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ABSTRACT

This four-part primer is designed to: (1) help Minnesota teachers acquire some familiarity with basic energy structure and language; (2) provide a capsule summary of Minnesota's energy picture; and (3) demonstrate that it is relatively easy to participate in energy education. Part 1 discusses: the fossil fuel age; kinds and forms of energy; energy units; energy efficiency (applying the rules of energy transformation); net energy; convection, conduction, and radiation; and exponential growth. Parts 2, 3, and 4 examine Minnesota's energy picture. Part 2 discusses coal, natural gas, petroleum, propane, electricity, and nuclear energy. Part 3 considers Minnesota's opportunities for energy conservation. Part 4 examines alternative energy sources and district heating and cogeneration. The alternative sources discussed include solar power (active and passive thermal, photovoltaic electric, thermal electric, and chemical fuel), hydro power, wind power, and biomass. Part 4 also considers two equity issues related to people and states and provides a short list of questions to help teachers and students in learning about energy. (JN)

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AN ENERGY PRIMER FOR MINNESOTA TEACHERS

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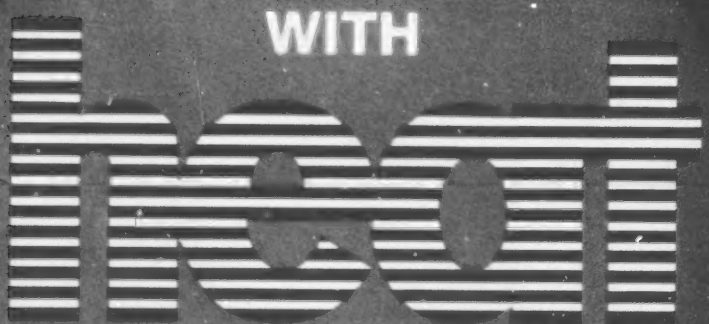

YOU NEVER HAVE TO ASK DIRECTIONS

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MINNESOTA DEPARTMENT OF EDUCATION
MINNESOTA DEPARTMENT OF ENERGY, PLANNING AND DEVELOPMENT

PURPOSE

This primer has three main purposes: 1. to help you acquire some familiarity with basic energy structure and language; 2. to provide you with a capsule summary of Minnesota's energy picture; and 3. to convince you that it is relatively easy to participate in energy education.

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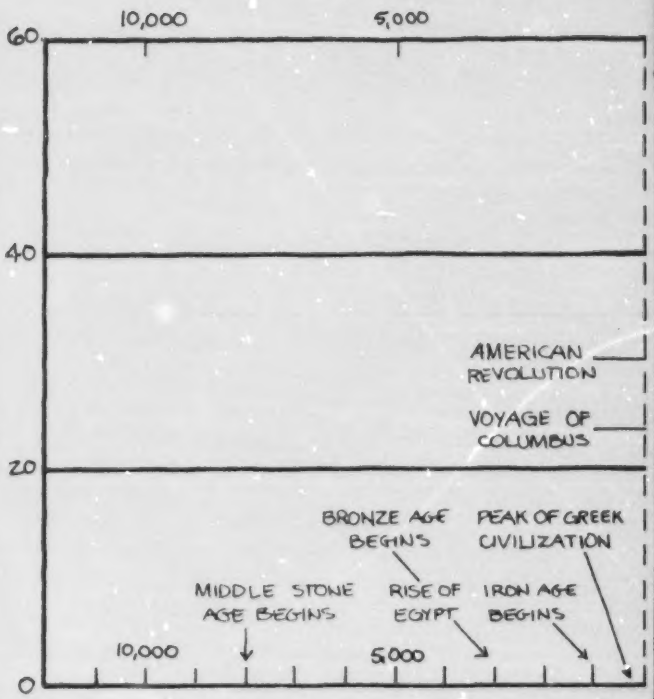
The Fossil Fuel Age



Most of the energy that runs life on Earth comes from the sun.

At a restaurant, the sun's energy comes in packages that take only a few months or a year or two to make. The energy in them left the sun only a couple of years ago. That's all the time it takes to grow a chicken or a fish or a calf. It takes even less time to grow a lettuce leaf, so the energy we eat is very young sunlight.

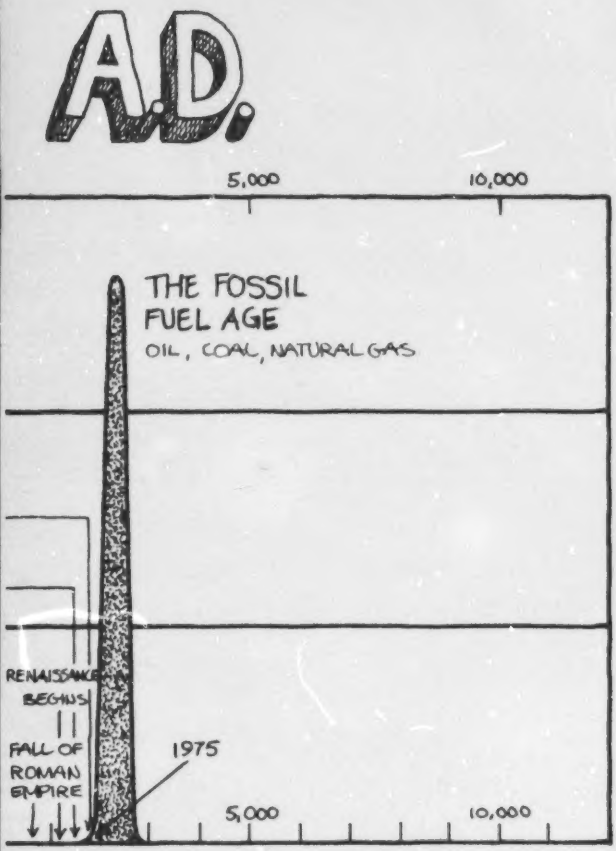
On the other hand, when our cars have breakfast, lunch or dinner at a gas station or when we heat our homes with oil or natural gas, the sun's energy comes in packages that took hundreds of millions of years to make.

In just 75 revolutions of Earth around its star, we have managed to burn up some 600 million years of buried life—fossil fuel—from that star, our sun.

Our world is a world of machines that run on fossil fuel energy. And, in all this time, nothing has come along that gives us such a rich shot of energy at such a low cost as oil and gas have done.

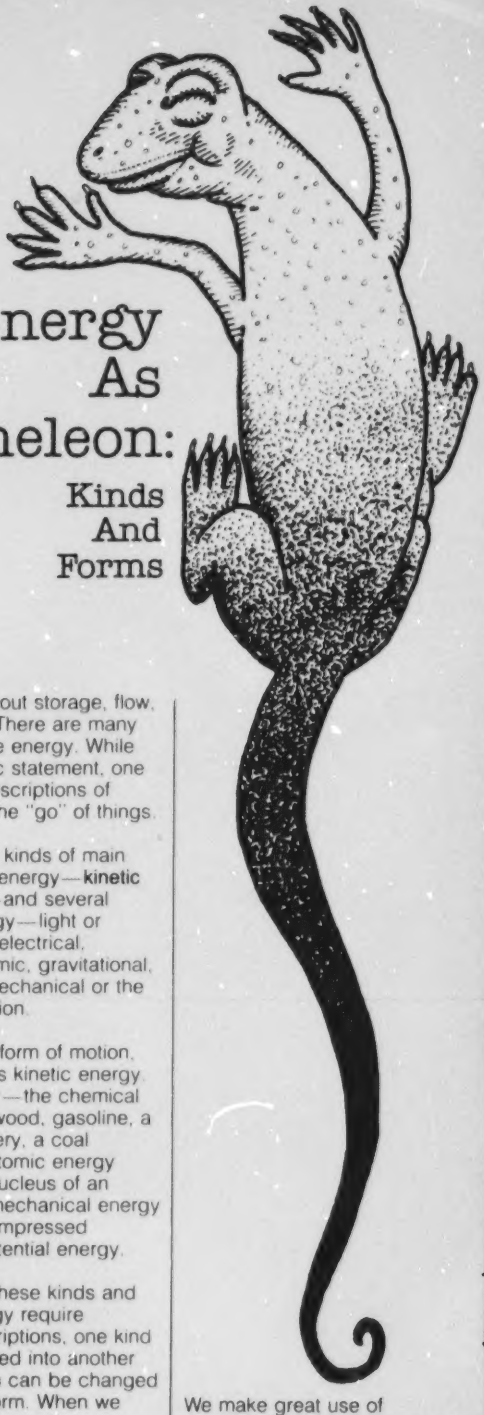
As the fossil fuel bank account runs out, the cost of energy goes up.

We are perched somewhere near the top or on the downhill



side of what geologists call "Hubbert's pimple," after M. King Hubbert, who popularized the curve of oil and natural gas use over time that goes from zero in 1850 to zero in 2100, with a climb and descent in between. It is important to emphasize that estimates of the oil and natural gas yet to be found in the United States in areas such as the Arctic Slope, the Beaufort Sea, the Atlantic Outer Continental Shelf, the deep waters of the Gulf of Mexico, and the Rocky Mountains Overthrust Belt, vary. How much oil and gas remains to be discovered? It depends on whom you ask.

The **Project Independence Report** (1977) had this to say: "Half of all the oil that has ever been produced has been taken from the earth in the last 10 years. This gives a perspective on the escalating growth in world energy demand. Even in the OPEC countries, as in most producing basins of the world, most of the oil has already been found. So great is the accelerating demand for energy that the years of abundant supply of conventional liquid hydrocarbons will be relatively few."



Energy As Chameleon:

Kinds And Forms

Energy is about storage, flow, and change. There are many ways to define energy. While not a scientific statement, one of the best descriptions of energy is as the "go" of things.

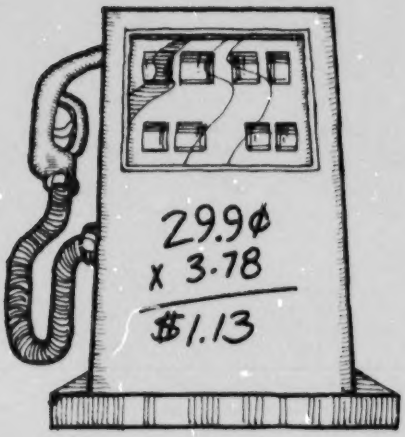
There are two kinds of main categories of energy—**kinetic** or **potential** —and several forms of energy—light or radiant, heat, electrical, chemical, atomic, gravitational, sound, and mechanical or the energy of motion.

Energy in the form of motion, heat, or light is kinetic energy. Stored energy—the chemical energy in firewood, gasoline, a flashlight battery, a coal deposit, the atomic energy found in the nucleus of an atom, or the mechanical energy stored in a compressed spring—is potential energy.

Even though these kinds and forms of energy require different descriptions, one kind can be changed into another kind; one form can be changed into another form. When we want to move something or heat an object or light a room, that is, whenever we want to do something to matter, we use the kinetic energy made available when one energy form is changed to another. The way we use energy is through its conversion into a different form.

We make great use of information and technology to do these things. A hydroelectric plant changes the gravitational energy of water to electricity; a lightbulb changes electrical energy into light and heat; an automobile changes the chemical energy of gasoline into heat and some of the heat into motion.

Making Energy Language Common



"What's the price on that pump?" the customer asked.

"That's 29.9 cents a liter," the attendant explained. "You must multiply that by 3.78, and you get the price per gallon, which is $1.13."

"I don't care, just give me $10 worth," the driver said. "I've seen that metric stuff before, but I never got wrapped up in it. It's like that kilowatt stuff."

"Kilowatt?"

"Sure, I was up in Canada, and all the miles on the streets have been changed to kilowatts," s/he said. "It's hard to figure how far anything is. Why can't they do anything in the American language?"

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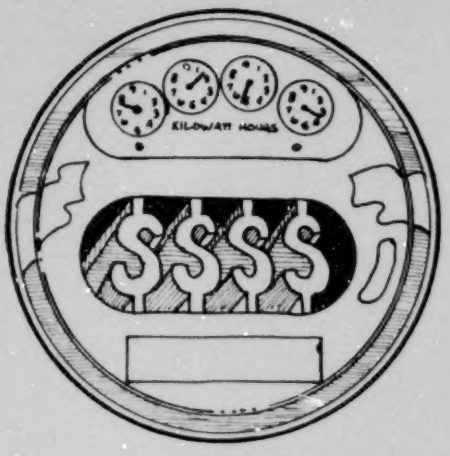
Given the wide variety of energy audiences, the use of many different energy units is inevitable. Physicists use electron volts, ergs and joules. Engineers use British Thermal Units, foot pounds and watt hours. Biologists (as well as dieters and nutritionists) think in terms of Calories.

The most common of these units can be easily converted into BTU's: The BTU, or British Thermal Unit, is the amount of energy required to raise the temperature of a pound of water one degree Fahrenheit. So,

- to convert from Calories to Btu, multiply by 4;
- to convert from Kilowatt Hours to Btu, multiply by 3,400; and
- to convert from Cubic Feet of Natural Gas to Btu, multiply by 100,000.



Energy and Power: What's The Difference?

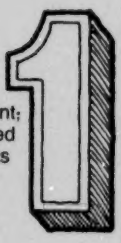
Energy and power are not synonyms. To physical scientists, energy simply means the ability to exert force and move things: our bodies, chunks of the earth, electrons in a wire or molecules in a solution. Power is how fast energy is produced or used. Time is involved in its definition.

Watts (w) and Watt-hours (wh)

Watts, kilowatts, and kilowatt-hours are such common and important words in the energy lexicon that they deserve some special attention. Watts are a measure of the flow of energy at a given instant. The watt-hour is used to measure the amount of energy actually used or produced over a period of an hour. Prefixes added to the watt and the watt-hour are used to multiply them into thousands (kilo-, k), millions (mega- M), or billions (giga-, G).

Electric power plants are described in terms of the maximum power output they produce at a single instant, and electrical appliances in terms of the power they can use in a single instant. There are 1000-megawatt (millions) power plants and 1000-watt hair dryers. In the utility industry demand, power, or load are used to express the rate at which energy flows. The electrical energy consumed in our homes, businesses, and schools is measured in multiples of watt-hours, e.g., home electric bills measure monthly consumption in kilowatt-hours (kwh).

The Rules of Energy Transformations



All matter and energy in the universe is constant; it cannot be created or destroyed but its form can be changed.

Energy flows are regulated by the laws of thermodynamics - rules that are easier to use than they are to understand. They are absolutely vital to thinking about and asking correct energy questions. In our search for energy efficiency we use them to find out where energy is lost and how to stop some of the losses and to achieve ways of using as little energy as possible to get a task done. These two powerful and pervasive rules are called the First and Second Laws of Thermodynamics.

Energy always flows naturally from hot to cold, *never* the reverse.

The First Law, the energy accounting principle, states that all matter and energy in the universe is constant, that it cannot be created or destroyed but its form can be changed when energy is transferred from one form to another, e.g., heat into motion, no energy is lost or gained in the process. This law can be written in a variety of ways. "You can't get something for nothing" or "There Ain't No Such Thing As a Free Lunch." The First Law means it's possible to account for and follow energy flows: where the energy is lost and where the energy can be saved in an energy transformation.

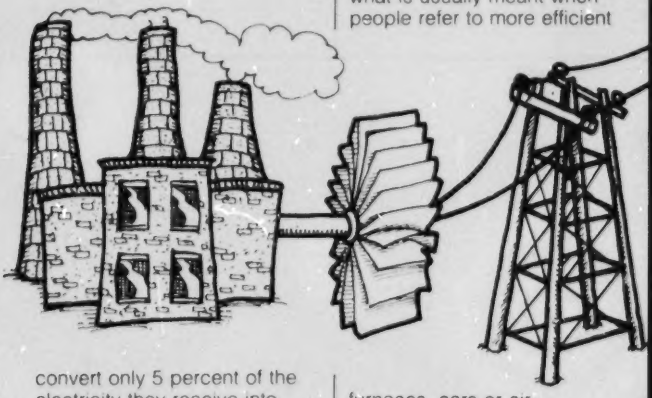
If the First Law of thermodynamics is true, why is it that we can't use energy again and again without ever running out of it? The answer lies in the Second Law of thermodynamics. The Second Law* tells us that energy cannot be recycled and that matter can only be recycled by expenditures of energy - always at less than 100 percent efficiency. This means every time energy is used to do anything, a whole lot of it can never be used again to do any more work. The Second Law says "In the energy game you can't break even." There is always a heat tax!

The Second Law assigns a direction to energy: it always flows naturally from hot to cold, **never** the reverse.

** The Second Law is also known as the Entropy Law. Entropy is a measure of the amount of energy no longer available for "work" or of disorder.*

Efficiency:
Applying The Rules Of Energy Transformation

One way to think about efficiency is that it is the opposite of waste. Energy resources can be lost before they are used as well as when they are used. Some energy resources are lost in their distribution, for example, through oil and gasoline spills and leaks. However, the major losses of energy occur during the conversion of energy from one form to another. Lightbulbs convert only 5 percent of the electricity they receive into light; the rest is lost as heat.



The functions that energy provides such as heating, cooling, lighting, and mechanical motion are known as energy services. We forget sometimes that energy services are the things for which we value energy. Oil, coal, natural gas, uranium and solar energy are used to provide these energy services. Energy efficiency is about how energy services can be performed with less energy.

Efficiency based on the First Law of Thermodynamics is about budgeting energy quantities, about ways to save Btu's, about conserving energy resources. First Law Efficiency is concerned with these kinds of questions: Where is energy lost? How can these losses be stopped or reduced as much as possible? Answers to these questions include things like sealing up energy leaks and using technology to improve the efficiency of the energy converting device. The latter is what is usually meant when people refer to more efficient furnaces, cars or air conditioners. The emphasis is on improving the performance of the device.

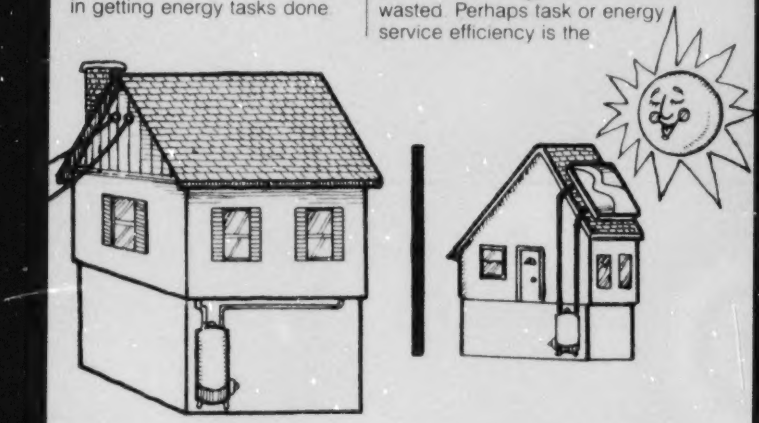
There are limits to First Law efficiency because in any conversion process, heat is always lost to the environment. In other words, there is a limit to the amount of an energy resource that can be converted to an energy service. It's **the** law!

The Second Law view of energy efficiency forces a shift in attention from energy quantities to differences in energy quality. In thermodynamics, quality refers to the temperature of the energy source. It tells how much energy is available to do work. Energy at high temperature can do a lot of work and vice versa.

The kind of questions Second Law Efficiency is concerned

with include: How much energy is required to get a task done? What use is a particular energy source especially good for? Can we match the quality of energy available with the quality needed? It tells us to use as little energy as possible in getting energy tasks done.

little room for improvement. This is First Law Efficiency or device efficiency. There is not yet general agreement on the calculation or Second Law Efficiency but furnaces are less than 10% efficient. More than 90% of the energy in the fuel is wasted. Perhaps task or energy service efficiency is the



Electricity, produced by the high temperatures of power plants (and with a loss of two-thirds of the original fuel energy), is often used for low quality energy services, such as heating hot water. When we use a high quality energy source to perform a task which only requires low quality energy, there is a great loss in efficiency. From the point-of-view of thermodynamics, it would be better to provide low temperature water heat with low quality solar energy, not high quality electricity. In other words, electricity may be the best way to run a washing machine. From a thermodynamic quality point-of-view, it is not the best way to heat the water for it.

When we read that an oil or gas furnace has an 80% efficiency there seems to be

standard against which our energy devices should be measured. A challenge to scientists, engineers, technicians and inventors is how to meet our energy service needs using as little energy as possible in getting tasks done. This involves both energy-efficient technologies and the use of appropriate renewable energy resources. We need to learn to use our fossil fuels for energy conversion processes for which they are best suited and learn to substitute appropriate alternative energy sources for those processes that they do best.

What are some reasons for interest in energy efficiency? Energy efficiency helps us reduce energy consumption while not reducing our standard of living. It saves money and conserves our fossil fuel reserves. One of the best reasons is that it reduces the pollution to the environment which results from energy conversion processes.

The Net Is The Thing

Every energy production process has its own energy costs. This concept is called NET ENERGY. Net energy is the energy amount remaining after the energy costs of discovering, producing, refining and distributing energy have been paid. It takes energy to get energy.

The net energy concept is a result of the workings of thermodynamics. Whenever we get energy we must use energy in one of its existing forms (Law I) and in the process we pay an energy tax (Law II).

This means that no energy source and conversion process is free—nor even the sun—but some may be cheaper than others. While it is easy and important to think about energy conversion processes in terms of a net energy equation, in the real world it is not always as easy to collect the necessary data, state the assumptions or calculate the gains and losses of a particular energy conversion process.

NET ENERGY

EQUALS

TOTAL ENERGY OUTPUT

MINUS

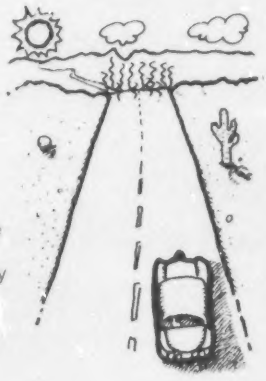
TOTAL ENERGY INPUT

The Way Heat Moves: It Isn't Too Clever!

Heat transfer occurs by three basic mechanisms. In each of these, heat always flows from warmer areas to cooler areas, warming them in turn. The greater the temperature difference between the warm and the cool surfaces, the greater the heat flow between them.

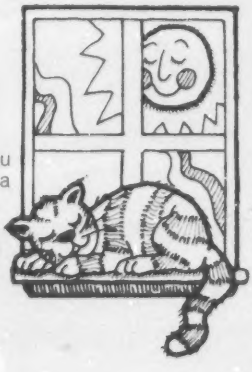
Heat is always predictable: it is always moving from hotter places to cooler places; however, the transfer is slowed when heat is guarded by insulation. Nevertheless, heat eventually escapes whenever it is next to a cooler place.

There are three ways that heat moves:



Convection:
This is the transfer of heat by moving currents of air (gases) or liquids. Have you ever noticed the shimmering of air currents over a paved road on a sunny day? That's convection!

Conduction:
Conduction is a process in which heat energy is passed from one fixed particle to another fixed particle. Have you ever sat too long on cool, damp soil in the spring or fall or put a metal spoon in hot soup and held the handle? That's conduction!



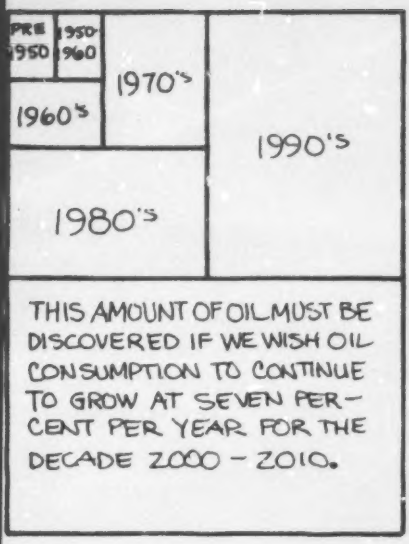
Radiation:
This is heat transfer through space. If you have ever stood in front of a fireplace or a hot stove and felt warm, you have experienced heat transfer by radiation. Have you ever seen a cat curled up in a sunny window on a cold winter day? That's radiation!

How Quickly Numbers Can Add Up

Many years ago a clever mathematician presented her king with a chess board and taught the king to play the game. As a reward the mathematician requested not gold but grain. She asked the king to place 1 grain of wheat on the first square, 2 grains of wheat on the second square, 4 grains on the third square and continue placing twice the number of grains on each successive square. The king quickly agreed. The fourth square required 8 grains, the twelfth square required 2,048 grains and the twenty-ninth square required 268,435,456 grains. The king's granaries were exhausted long before the sixty-four squares were filled.

To give you an idea of how much grain it would take to fill the chessboard, Albert Bartlett, of the University of Colorado, has calculated that it is approximately 500 times the 1976 annual worldwide harvest of wheat! This is an example of the deceptive effects of exponential growth. It is characterized by doubling. Each doubling exceeds the sum of all previous doublings. To cover any square, one grain more is added to the total number of grains already on the board, e.g., the 64 grains on square 7 are one more than the total of 63 grains already on the board. How numbers grow!

What does exponential growth have to do with energy? It can help us begin to understand one of the central issues in the energy debate—when will we run out of oil, coal, uranium, wood, etc? World oil consumption has doubled approximately every 10 years since 1890, though it grew at an average of "only" 7% per year. The significance of the historical 7% growth rate in world oil consumption can be shown graphically.


PRE 1950
1950-1960
1960's
1970's
1980's
1990's
THIS AMOUNT OF OIL MUST BE DISCOVERED IF WE WISH OIL CONSUMPTION TO CONTINUE TO GROW AT SEVEN PER-CENT PER YEAR FOR THE DECADE 2000 - 2010.

1. The top half of the graph represents known petroleum resources.
2. The area of each rectangle represents the amount of petroleum consumed.
3. From 1950 on, the quantity of oil consumed in a decade is as much as in all preceding time.

Graphical model developed by Mario Iona, from "Forgotten Fundamentals of the Energy Crisis," Albert J. Bartlett, ***American Journal of Physics,*** *September 1978. Used with permission.*

You will hear arguments that estimates of energy reserves are imprecise and that new discoveries will be made. And that oil shales and tar sands will save us. However, the implications of doubling time remain the same. As you can see from the diagram even a doubling of current petroleum estimates would add only one more doubling time. This is because at a constant rate of growth the amount consumed during each doubling time is more than has been consumed in all previous doubling periods!

An understanding of exponential growth will help you to evaluate projected energy supplies. There is one really important question you should always ask when you see or hear a new energy projection. Is the rate of growth per year stated? Is the life expectancy of the resource based on zero growth or an increase in consumption? The chart below can help you evaluate projections.

At the current 7% annual growth how long would a 500 year supply of coal last? Find 7 under the column labeled "Rate of Growth." Then move right to the column labeled "500 years." There you will find 51 years. You can see from this chart that any increase in coal use from a zero growth rate always results in less than a 500 year supply. No matter what anyone says!

Rate of Growth	Years Remaining of Resource							
ZERO	10.0	30	100	300	500	1000	3000	10,000
1%	9.5	26	69	139	179	240	343	462
2%	9.1	24	55	97	120	152	206	265
3%	8.7	21	46	77	92	115	150	190
4%	8.4	20	40	64	76	93	120	150
5%	8.1	18	36	56	65	79	100	124
6%	7.8	17	32	49	57	69	87	107
7%	7.6	16	30	44	51	61	77	94
8%	7.3	15	28	40	46	55	69	84
9%	7.1	15	26	37	43	50	62	76
10%	6.9	14	24	34	39	46	57	69

Minnesota's Energy Picture:

Living Off The Past

Minnesota is sometimes described as "energy poor." The state lacks sources of all of the major traditional fuels. Therefore, the problem of an energy supply for Minnesota is a real and permanent one. A number of variables affect the amount of traditional energy sources that will be available to Minnesota in the future. Some of these include: (1) geological processes, millions of years ago, that set limits to fuel availability; (2) decisions made in Canada, Mexico, and the OPEC nations; (3) the economics of energy exploration, development and research; (4) U.S. government energy policies, e.g., on pipelines, offshore drilling, incentives and subsidies for conventional and unconventional energy alternatives; and (5) environmental impacts of the production, transportation and consumption of energy.

You can think of Minnesota as a system of energy—an energy transformation system powered from outside by energy. The state, like a giant organism, combines solar, other natural energies and purchased energies to produce a rich variety of products. The products are exchanged for goods, services and materials. Money is used to keep account of the energy flows—the exchange of materials, goods and services—although it does not account for the free public services provided by nature, e.g., the contribution of sunlight to agricultural and timber production.

2

LIVING OFF THE PAST

18

Coal

Coal is a solid, combustible material formed by the decomposition of plant material in the absence of air. It is about 75% carbon.

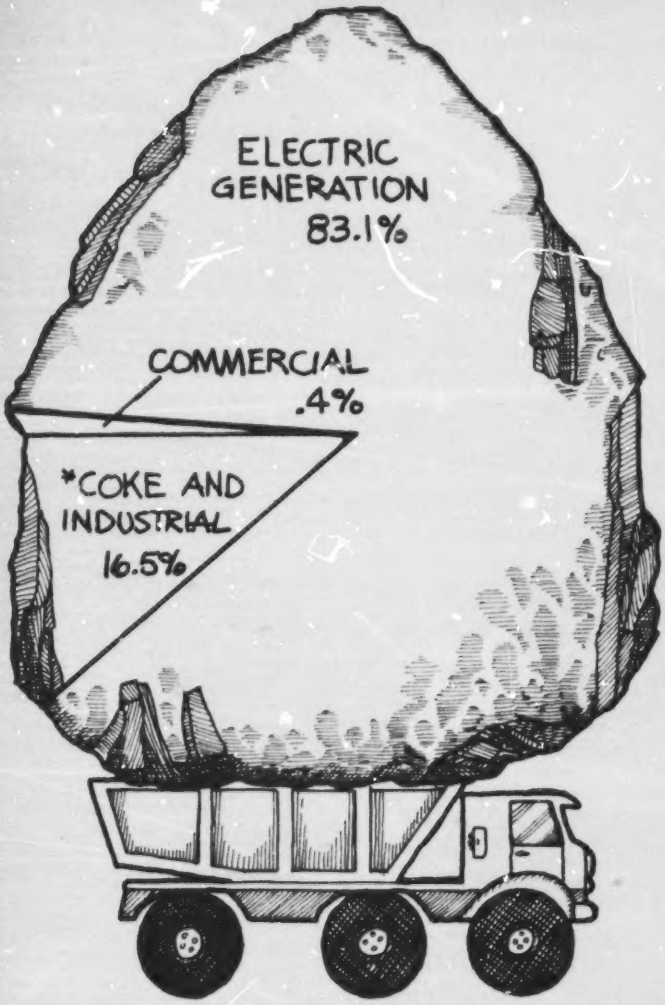
In 1976, Minnesota received 74% of its coal from Montana, Wyoming, and North Dakota. By 1978, 86% came from these states; the remaining 14 percent came from eastern mines. The trend toward greater use of western coal is expected to continue because of the large coal reserves available in the West and their proximity to Minnesota.

Most coal is shipped to Minnesota by unit trains—90-110 cars, each holding about 100 tons of coal. They run a continuous circuit between the mine and the plant. The major route enters the state at Moorhead. Each of four electric generating plants—Sherco, A.S. King, Clay Boswell, and Black Dog—use more than one million tons of coal a year.

The price of coal is composed of three parts: the costs of coal at the mine, taxes, and transportation costs. They are all increasing. In 1970, the cost of Montana coal at the mine was $1.65 per ton; in 1979 it was $5.38 per ton. In 1970, Montana taxes were $.08 a ton; in 1979 it amounted to $1.61 a ton. The cost of shipping a ton of coal from Montana to the Twin Cities was $3.70 a ton in 1970; in 1979 it cost $9.27 a ton.

Coal production contributes to serious environmental effects. These include: dust from strip-mined land, degraded water quality, and disturbance to other land uses such as grazing. Socioeconomic effects also occur from the influx of people into small towns as mines are opened and operated.

Some environmental effects of coal consumption include: the release of sulfur dioxide and nitrogen oxides, pollutants causing acid precipitation (a major global problem, the BWCA is particularly sensitive); an increase in atmospheric carbon dioxide, the effects of which are uncertain; the release of hazardous trace elements such as arsenic, mercury, and lead; thermal and other water pollution; and a massive solid waste disposal problem—in 1977 coal- or fly-ash was the 6th most abundant mineral in the U.S. Unit trains also present communities with many problems: noise, air



1978 Coal Consumption in Minnesota by Sector

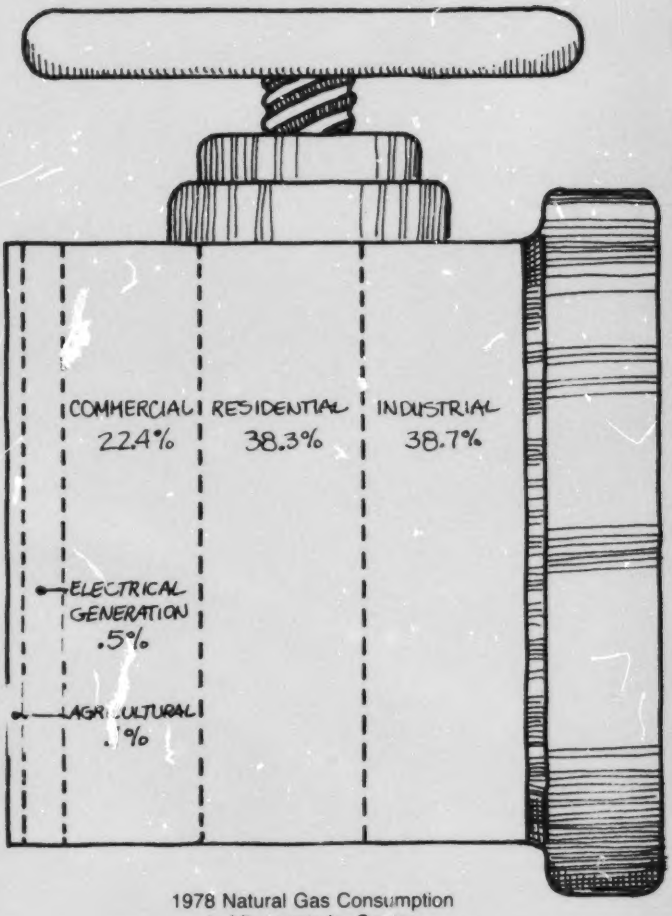
pollution, land-use impacts, traffic congestion and accident hazards.

The primary constraints on increased coal use will be the large environmental impacts associated with the production, transportation, and consumption of coal and, for large industries, the economic costs associated with conversion from natural gas and petroleum to coal burning.

Coal's future also depends on better methods to convert coal to usable energy. At present much of the energy in coal used in electrical generation and industrial boilers is lost as waste heat. In addition, significant air pollution problems associated with direct burning of coal limit its use.

** When coal is heated in a closed industrial oven with a limited supply of air, the product is coke. It is more nearly pure carbon than coal and is used in the manufacture of steel and in the extraction of certain metals from their ores.*

Natural Gas
(Methane)



1978 Natural Gas Consumption
in Minnesota by Sector

Natural gas is formed by the same processes which form oil. It is found under the earth's surface, often in association with petroleum. Natural gas consists primarily of methane, a compound of hydrogen and carbon.

Minnesota receives about 93 percent of its natural gas from Texas, New Mexico, Oklahoma, Kansas, Montana, and Louisiana; the other 7% is obtained from Canada and is used in northern Minnesota. An extensive pipeline system connects the gas well to the consumer. Over 1 million miles of pipelines, ranging in diameter from 1" - 42", exist in the U.S.

Natural gas burns cleanly without giving off odors or particles, which makes it well suited for such residential and commercial tasks as space heating, water heating, cooling and food and clothes drying. It is a popular fuel because it has few pollution problems and for many years has been the least expensive of the regular fuels.

The development and transportation of natural gas may have serious environmental effects. Gas development projects in coastal areas may have adverse effects on air quality and water quality and create aesthetic problems.

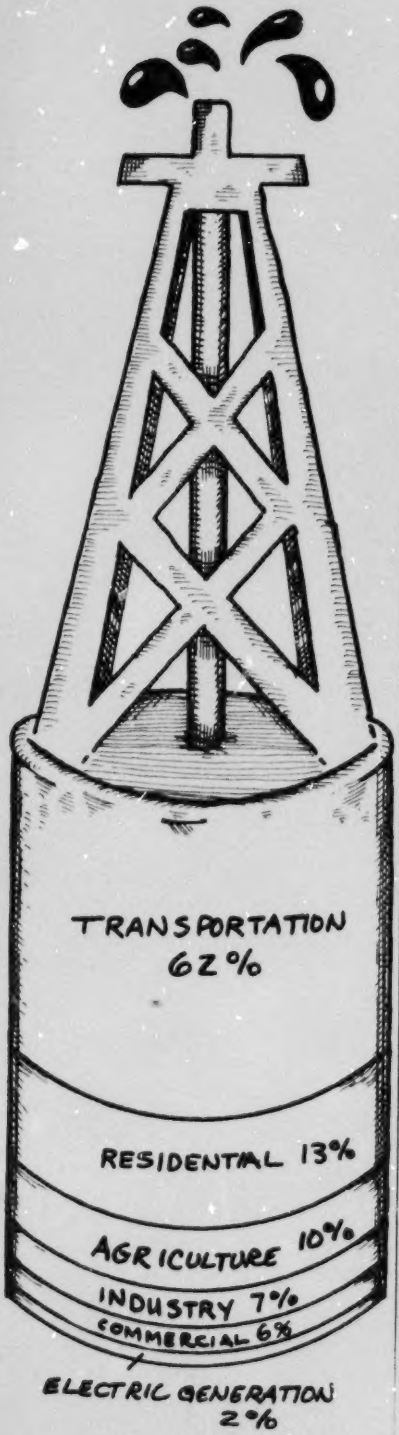
The amount of gas available to Minnesota in the future is affected by many variables. How much natural gas is still underground? How will costs of exploration and development affect supply? What are the environmental impacts of exploration? What will be the influence of world oil prices on natural gas production? How much natural gas will Mexico and Canada export to the U.S.?

The Natural Gas Policy Act passed by Congress in 1978 improved domestic distribution and stimulated exploration. Before this Act, natural gas sold to other states was held below the price of gas in the state in which it was produced. Since this Act there has been an increase in exploration. Whether such increased exploration will result in correspondingly greater addition to long-term gas reserves is not known.

New gas supplies from Alaska may be available in the mid-to-late 1980's via the 4,800 mile Alaskan pipeline. Finding money to finance this immense project has proved to be a large task. It is difficult to predict when this gas will begin flowing.

In January 1980, the U.S. Department of Energy denied any increase in imports of natural gas from Canada. Loss of Canadian gas imports could cause serious problems for thousands of residential customers with no alternate fuel systems in their homes. Such policy has important implications for Minnesota: use levels must remain constant and companies searching for new supplies will have to find them elsewhere.

Petroleum
(Oil)



1978 Petroleum Consumption in Minnesota by Sector

Petroleum is formed from the fossil remains of plant and animal sea life. It is a complex mixture of large molecules consisting of carbon and hydrogen. Oil is younger than coal, only a few tens of million years old instead of hundreds of millions.

Minnesota has an oil habit. Of all the energy the state uses, 41 percent is from oil. Minnesota's annual consumption of petroleum products has increased from 70 million barrels in 1960 to 116 million barrels in 1978. Perhaps you have wondered what a "barrel" of oil really is. It is 42 United States gallons of oil. This standard was made official in 1916 by an act of Congress.

All petroleum is imported from outside Minnesota and enters the state primarily through pipelines. There are three Minnesota area refineries which produce petroleum products from crude oil: Pine Bend, St. Paul Park, and Superior, WI. A 28-year-old oil refinery in Wrenshall stopped refining oil in May 1981. The plant has been mothballed to keep the facility ready for reopening or sale. At an oil refinery each barrel of crude oil is refined to produce several products. These include a variety of **refinery gases** used to make petrochemicals* and liquified petroleum gas (LPG) used for heating, cooking and agriculture; **gasoline**; **middle distillates** such as kerosene, heating and diesel oils used for space heating, boiler fuels and transportation; **residual fuel oils**

used in industry, schools and hospitals; and **asphalts** used for road building.

Storage of petroleum products plays a very important role in the supply situation. Gasoline inventories must be built in the spring; heating oil inventories during the fall. For a normal winter, a reasonable November inventory for heating oil is about 4 million barrels.

The central issue of Minnesota's oil dilemma is that we are at the end of the pipeline—absolutely dependent on oil imports from Texas, OPEC, Oklahoma and, until recently, Canada. In 1980, Canada supplied 24 percent of Minnesota's oil and has supplied as much as 86 percent. The oil is low-quality heavy crude** which Canada didn't want until 1973. Canada began to reduce its exports in 1974. Before this, the Canadian government preferred to import low-priced, high-quality light crude** from the Middle East.

Canadian crude oil will probably remain a significant source for Minnesota refiners throughout the early 1980's. A new pipeline, connecting Minnesota to southern crude sources, has reduced Minnesota dependence on Canadian crude, however.

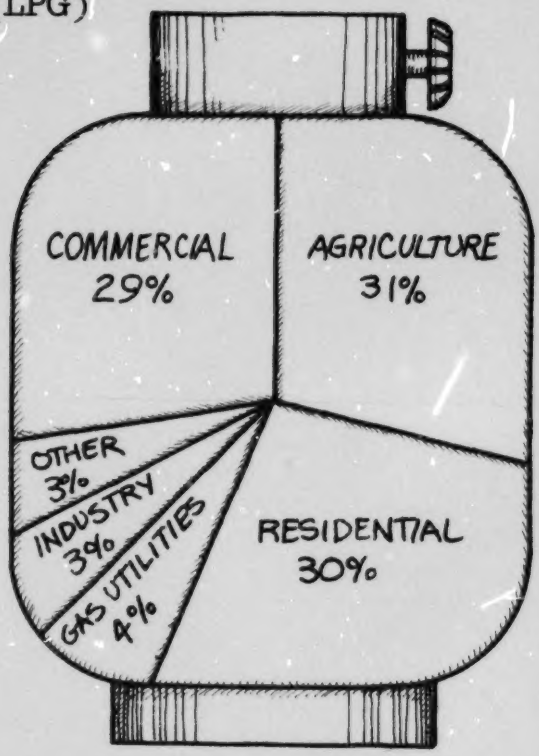
Oil prices were also deregulated in 1981. Before decontrol, 28 percent of the crude oil produced in the U.S. was limited in price. The price of this oil is now the same as the world market price. Some results of decontrol include: (1) consumer price increases for gasoline and heating oil; (2) increased leakage of Minnesota dollars to pay for oil imports slows down economic growth and employment opportunities; (3) reduction in the amount of income individuals can spend on non-energy goods and services which places a particularly heavy burden on the poor; (4) possible increases in alternative fuels production; and (5) increased conservation.

What the future holds is unknown but oil is likely to be a very troublesome energy factor for Minnesota, the United States and the world in the next two decades. Oil is no longer cheap; furthermore, the era of secure and safe oil supplies is now ended.

** Petrochemicals refer to oil and natural gas based products. What can you make from oil? Fake eyelashes, aspirin, disposable diapers, panty hose, flea collars, track shoes, bikinis, football helmets, hockey pucks, wash and wear clothing, fishing lines, pacifiers, volley balls, rubber duckies, underwear, deodorants, bearing grease.*

*** Heavy or "sour" crude is thick oil, rich in sulphur, a known and potentially serious air pollutant and used mostly for making certain fuel oils and asphalts. The refineries at Pine Bend and Superior, WI were designed to process heavy crude into gasoline, heating oil and diesel fuel. Low sulphur light or "sweet" crude is used for the manufacture of gasoline, high-grade heating oil and jet and diesel fuel.*

Propane
(LPG)



1978 Propane Consumption in Minnesota by Sector

Propane is a clean-burning fuel which makes it a premium fuel in high demand. It is used for space heating, cooling, water heating and grain drying. Much of west central Minnesota's turkey breeding requirements are met by propane. In rural areas without natural gas service, it is sold in cylinders and tanks.

The major industrial use of propane is as a back-up fuel when natural gas is curtailed. Gas utilities, primarily those in the 7-county metropolitan area of Minneapolis-St. Paul, use a propane-air mixture for space heating when natural gas demand exceeds supply.

Minnesota's propane supplies originate from underground storage facilities in the south central United States (Kansas, Oklahoma, and Texas) and western Canada (Alberta, Saskatchewan). It is expected that domestic propane supply will decrease as a result of declining natural gas production and the less-rich liquid petroleum content of future gas discoveries. Even so, a worldwide surplus of LPG is expected during the early 1980's. A major reason is the new gas processing capability being developed in petroleum producing nations. Until the recent energy price hikes, these countries had simply been burning off the natural gas and LPG found during oil exploration. Energy producers in the United States also used to do this. The practice is called flaring.

Despite these optimistic projections of propane supplies, the federal government is considering limiting LPG imports as part of its program to limit petroleum imports. If LPG imports are not limited, the Minnesota Energy Agency expects that supplies of propane to Minnesota will be sufficient to meet demand.

Electricity

Electricity is a **form** of energy, **not** an energy resource. Energy stored in oil, gas, coal, uranium or falling water is converted in a power plant to mechanical energy, which is then converted to electrical energy.

In the generation of electricity only 1/3 of the fuel's energy is converted to electricity; the rest is lost as heat to the environment. It is, therefore, important to use electricity only when it is the best way to get a job done, e.g., for lighting, appliances, and stationary motors and not for space and water heating. Less energy is lost when oil is burned to heat a home than when oil is burned to drive a generator that produces electricity to heat a home.

There is not yet a practical and cost-effective way to store large quantities of electricity during times when demand is lower. To meet varying levels of demand for electricity, utilities have three main types of generating capacity: baseload, intermediate and peaking.

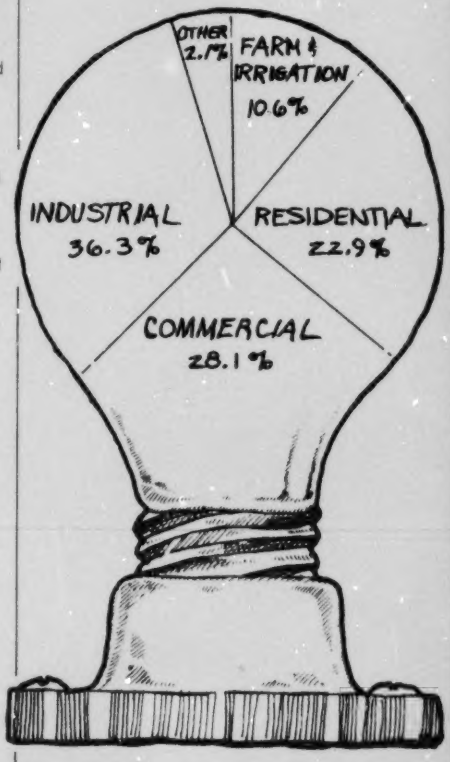
Baseload power plants are designed to operate at maximum output for long periods. Baseload units typically provide the bulk of a utility's total generation. They use coal or uranium as fuel.

Intermediate generating units are designed for flexible output. These plants are coal fired. In 1978, 40.1 percent of the electricity generated by NSP came from intermediate units.

Peaking plants are used only during those months when everybody is using a lot of electricity. Peaking units require relatively expensive fuels, such as fuel oil. Only 3 percent of Minnesota's electricity is generated from oil.

Projections of the demand for electrical energy to the year 2000 are widely divergent. Lower projections assume greater appliance efficiencies, progress in building standards, retrofitting (insulation, caulking, weatherstripping), and other forms of conservation.

The biggest increases in future demand are expected in the industrial and residential sectors. The latter is due to increased use of electrical space heating, appliances and new uses for electricity.



(security systems, saunas, hot tubs, home entertainment systems, etc.). There is a growing tendency to substitute electricity for tasks that previously used other fuels

Meeting new electrical demand will be costly. Electricity from a new baseload plant may cost 2 to 3 times as much as present baseload plants. The economic and environmental costs of meeting demand with traditional facilities and resources will need to be weighed against the costs of conservation and meeting demand with alternative resources.

Large electric facilities are of increasing concern to Minnesotans; for example: construction of coal-fired generating plants leads to increased coal mining, which adversely affects the air and water quality of the states where it is mined; large quantities of water are used to absorb the waste heat produced by generating plants; the use of water at generation facilities affects both water supply and water quality; recent accidents at nuclear facilities, such as those at Three Mile Island and at NSP's Prairie Island plant, have led to increased concern about the safety of these plants; there are also strong concerns about long-term storage of radioactive wastes, mining and processing of uranium and chronic low-level releases of radioactivity from reactors; and transmission lines affect land use and are perceived as an aesthetic problem in many areas.

A Comparison, 1978

Fuel Type	Minnesota	U.S.
Coal	58.4%	44.3%
Nuclear	35.4	12.5
Oil & Gas	3.4	30.3
Hydro	2.8	12.7
Other	0	0.2

Nuclear:
A Primer Within A Primer

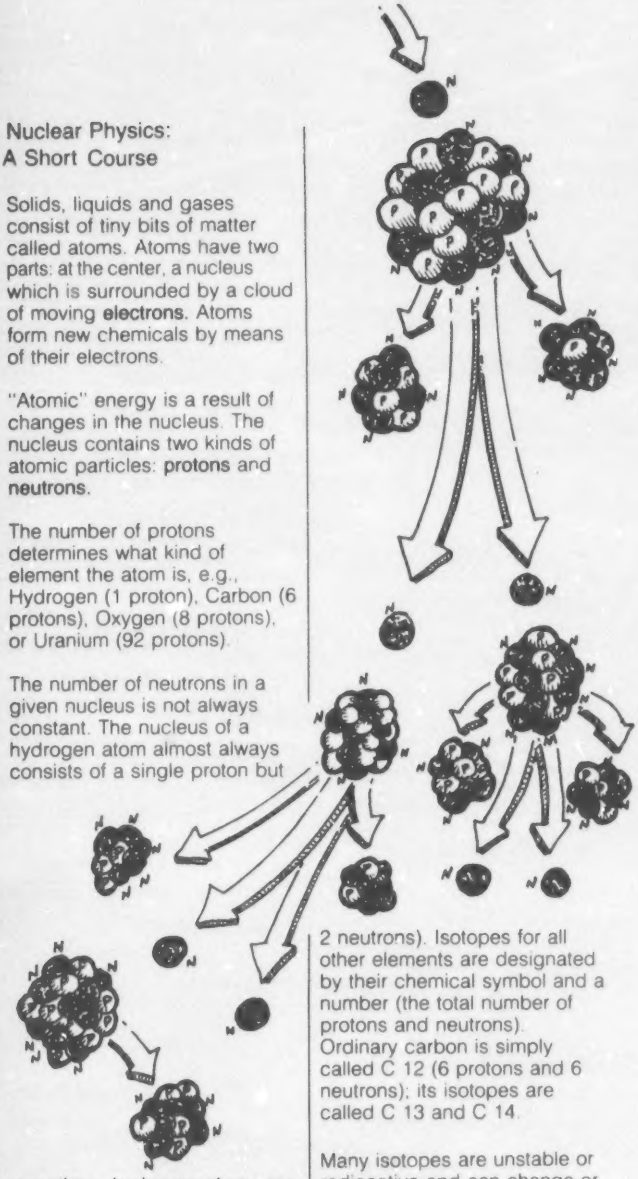
Nuclear Physics: A Short Course

Solids, liquids and gases consist of tiny bits of matter called atoms. Atoms have two parts: at the center, a nucleus which is surrounded by a cloud of moving **electrons**. Atoms form new chemicals by means of their electrons.

"Atomic" energy is a result of changes in the nucleus. The nucleus contains two kinds of atomic particles: **protons** and **neutrons**.

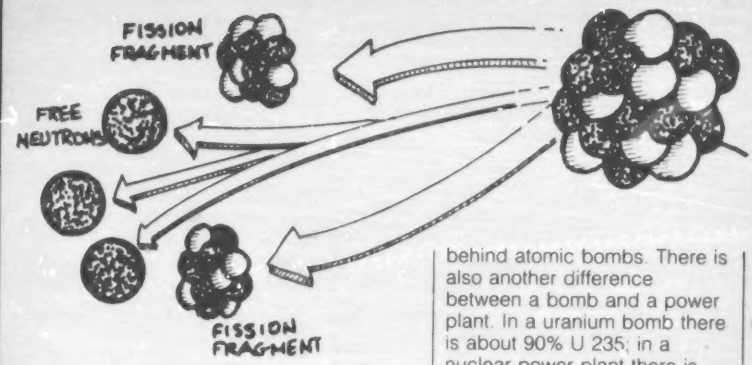
The number of protons determines what kind of element the atom is, e.g., Hydrogen (1 proton), Carbon (6 protons), Oxygen (8 protons), or Uranium (92 protons).

The number of neutrons in a given nucleus is not always constant. The nucleus of a hydrogen atom almost always consists of a single proton but



sometimes hydrogen atoms are found with one or even two neutrons. These hydrogen atoms are called **isotopes**; atoms with the same number of protons but different numbers of neutrons. They are heavier than ordinary atoms but otherwise have identical chemical properties. Hydrogen isotopes have their own distinct names: deuterium (1 proton, 1 neutron) and tritium (1 proton, 2 neutrons). Isotopes for all other elements are designated by their chemical symbol and a number (the total number of protons and neutrons). Ordinary carbon is simply called C 12 (6 protons and 6 neutrons); its isotopes are called C 13 and C 14.

Many isotopes are unstable or radioactive and can change or decay into more stable forms. This change process is described by a measure called the **half-life**. The half-life of a radioactive isotope can be very long (Uranium 238, 4 1/2 billion years), or short (Polonium 213, 4 millionths of a second). The half-life of a radioactive isotope is the period of time in which one half of the original number of atoms decay. Suppose we



start with 24 billion atoms of Uranium 238. In 4 1/2 billion years, 12 billion of the atoms would have decayed. In another 4 1/2 billion years, 6 billion of the remaining atoms would have undergone radioactive decay and so on.

When radioactive isotopes decay, energy is given off in the form of radiation. Radiation is energy that travels in rays or particles. There are two main types: **ionizing** — radiation from nuclear power plants, natural or background radiation, x-rays; and **nonionizing**—light and sound. While overexposure to nonionizing radiation such as sunburns, rock concerts and auto races can cause discomfort, it is not considered life threatening. Ionizing radiation is much more energetic and can interfere with vital functions of living organisms. In humans, such changes can lead to cancer and birth defects.

Atomic Fuel

U 235 (92 protons, 143 neutrons), an isotope of uranium, is used in the commercial production of electricity. Its nucleus can be split **(nuclear fission)** by a neutron. The nucleus breaks into two or three neutrons and fission fragments. These neutrons can split other nuclei and the released neutrons can split still other nuclei and so on. This is called a **chain reaction.** In an atomic power plant, the sequence is controlled by using materials that absorb neutrons in such a way that the number of neutrons is held constant. An uncontrolled neutron sequence, i.e., 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, etc., is the basic idea behind atomic bombs. There is also another difference between a bomb and a power plant. In a uranium bomb there is about 90% U 235; in a nuclear power plant there is about 3% U 235 and a nuclear chain reaction is not possible.

Some of the kinetic energy of the neutrons and fission fragments is converted into heat energy when they collide with the nuclei of surrounding atoms. The heat of fission is transferred to water to make steam which turns a turbine generator to produce electricity.

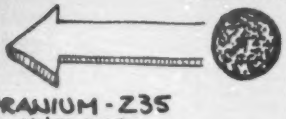
LWR's

Nuclear power reactors in use in the United States are called **light water reactors** (LWR's). The term light water distinguishes them from systems that use water made of heavy hydrogen (Deuterium), a design widely used in Canada. LWR's have four major parts: **fuel rods** which contain the uranium fuel; a **moderator** which slows neutrons down so that they are readily absorbed by other uranium nuclei; **control rods** which grab free neutrons and slow down the chain reaction; and a **coolant** which cools the fuel rods and carries heat to the electric generating turbine.

Minnesota has three nuclear power plants: a plant at Monticello started operating in 1971; 2 plants at Prairie Island in Red Wing started operating in 1973 and 1974. In 1978, 35 percent of the electrical energy produced in Minnesota was from nuclear power.

Some Effects

Nuclear power does not produce the air pollutants associated with fossil fuel plants. However, reactors have a special environmental impact. Operating a nuclear power plant inevitably leads to the release of radioactive materials into the environment. Is this radiation a significant or



insignificant threat to environmental and human health? Apparently qualified experts are found on both sides of the issue. The left-overs of the conversion process remain radioactive for a long time. There is still no national, safe, permanent waste repository nor is there an acceptable, long-term management plan for regulation of these radioactive materials.

And then there is the general issue of safety. **The Report of The President's Commission on The Accident at Three Mile Island** noted that "after many years of operation, the belief that nuclear power plants are sufficiently safe grew into a conviction. The Commission is convinced that this attitude must be changed to one that says nuclear power is, by its very nature, potentially dangerous, and, therefore, one must continually question whether the safeguards already in place are sufficient to prevent major accidents."

The Breeder

The fuel used for LWR's, Uranium 235, is a rare natural resource. It makes up less than 1% of uranium ore. The rest is Uranium 238 which can't be split by the slow moving neutrons in a LWR.

In a breeder reactor—named because it increases (breeds) the number of neutrons during fission—Uranium 238 is bombarded with "fast" neutrons and converted into plutonium-239. When a neutron collides with an atom of plutonium-239, the atom breaks apart and creates a lot of heat. Like the LWR, the heat is used to boil water to make steam which turns a turbine generator to produce electricity. The breeder does not create more energy than it started with, it makes more of the energy in the uranium fuel available. Remember your thermo-dynamics.

The United States has a large-scale demonstration breeder reactor project, a partnership effort of government and industry, in Tennessee. Worldwide, 11 breeder reactors are operating, 4 are under construction and 9 others are planned.

For most critics, the most serious problem posed by the breeder centers on plutonium. The breeder greatly increases its amount. Plutonium is the raw material for the nuclear explosives. Breeders enhance the possibility for its diversion by governments for military purposes.

Fusion

Energy is also released when two light nuclei combine or **fuse,** to form a heavier one. Think of fusion as the opposite of fission. Stars are natural fusion reactors. Their very high temperatures and pressures fuse the nuclei of hydrogen atoms together to radiate heat and light.

On earth, fusion reactors unite deuterium and tritium, isotopes of hydrogen, to create a new nucleus and a free neutron. In the process of bumping into other nuclei, some of the kinetic energy of the free neutron becomes heat that can be used to make steam to turn a turbine generator to produce electricity. Deuterium is a rare isotope (about one out of every 6500 atoms), but because water is so abundant the supply can be described as limitless.

Fusion has a much smaller radioactivity and waste-disposal problem than fission reactors, and the scientific principles of fusion are well known. The challenge for the future in fusion is engineering development and technology. Designing equipment that will withstand the extremely high temperatures and enormous forces represents challenging engineering problems. The United States hopes to have a demonstration plant by around the turn of the century.

Minnesota's Energy Picture:

Opportunities For Conservation Energy

Many of us think of energy conservation as deprivation. Of doing without—turning down thermostats to uncomfortable levels, driving much less, and producing fewer products than we do now.
Have you ever thought of energy conservation as an energy SOURCE or as an energy ALTERNATIVE or as more EFFICIENT use of energy rather than doing without? Because that is what it is.

In 1980, Minnesota's energy bill was over $6 billion. By 1985, it may be $12 billion. And by 2001, our energy bill could be $30 billion. Much of this money is being drained from the state economy to energy-producing states and nations to pay for fuel and for taxes on these fuels. Energy in...dollars out. Nearly $12 million a day. If only some of this money could be made to circulate within Minnesota. The economic benefits of these savings—it would be a kind of "new" money available to Minnesotans—would be substantial: jobs would be created, consumers would save money; in short, our economy would be stimulated. How can we decrease this mega-dollar drain? There must be **something** Minnesotans can do. There is!

We must become preoccupied with energy conservation. For these things to happen, conservation—energy conservation—must become as important as alternatives are to Minnesota's approach to energy. Energy conservation is an enormous, untapped potential. It can provide more energy, at lower cost and more quickly than **any** other energy source available in the next 20 years. Just think of that! By 2000, it can lower our energy use by almost 20%. Furthermore, energy conservation is gentle toward the environment. All we have to do is take advantage of the opportunities. And there are 1000's of them; big, medium and little. In energy conservation, even little things mean a lot.

RESIDENTIAL CONSERVATION

Minnesota housing consumes about 23% of the state's energy, mostly for heating: space and water. We are a long way from meeting our potential for residential conservation. In one recent survey, 55% of homes had less than 6" of attic insulation; 12% had none.

Weatherizing existing buildings is known as retrofitting. It is based on the principle of doing first things first; doing things in order of greatest energy savings for lowest cost. The procedure for analyzing which things to do first is known as an "energy audit."

Thermostat adjustments cost nothing, but they save fuel. Air leaks and drafts should be reduced by caulking and weatherstripping. When all air leaks are added up they can equal a fully open window all winter long.

The effectiveness of different types and thicknesses of insulation is indicated by "R-value." R-value is a measure of how well a material Resists transmitting heat - in other words, how well it will keep heat from passing through the walls, ceilings, and floors of a home. The higher the R-value, the more effective the insulation.

We must also be concerned with improving the energy performance of new houses. A major revolution in housing is the superinsulated house. These houses are so efficient they no longer need a furnace. For back-up heat on very cold winter days, these conservation houses use electric baseboard units, wood furnaces, and sometimes oil and natural gas furnaces, although most manufacturers don't build furnaces that are small enough! Several of these houses have been built in Minnesota and heating bills average $100 for the year.

Some key features include: massive amounts of insulation; most of the house's windows (70-90%) are on the south-facing wall of the house; a tight vapor barrier (the house is literally wrapped in a plastic bag to stop air leaks, keep heat inside and to prevent condensation of water in the walls); double walls; an air exchanger (see below); and entrance hallways or vestibules which insure there are always two doors between the outside and inside of the house. Normally, the heat generated inside the house from people, lights, appliances and sunshine is more than enough to keep the house at comfortable levels. Here...in the winter. Even in the prairie provinces of Canada.

Superinsulated houses are so well sealed that one of the big concerns is indoor air pollution: odors; moisture build-up; stale air; formaldehyde from cabinets, rugs and furniture; gases from unvented gas cooking; and radon, a radioactive gas produced by radium which is found in building materials such as concrete and brick. The answer is an air-to-air heat exchanger which dehumidifies the air, sends out warm, stale air and applies the heat from it to incoming fresh, cold air.

COMMERCIAL CONSERVATION

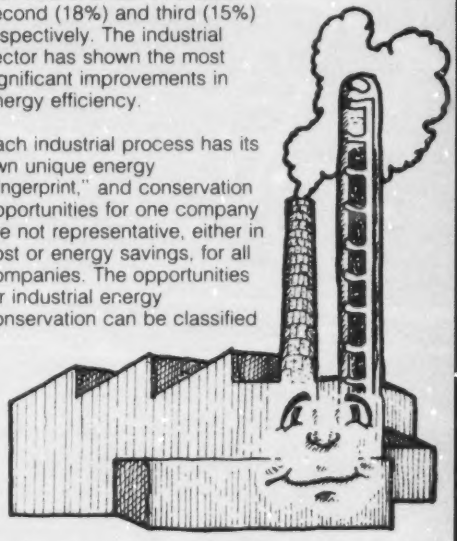
The commercial sector includes diverse energy users—offices, stores, schools, highway lights, hospitals, shopping centers, hotels, restaurants and warehouses. The commercial sector uses about 14 percent of Minnesota's annual energy supply but accounts for one-third of all electricity use. An aggressive conservation program could be very important in reducing the need for power plants.

Dramatic savings are possible in existing buildings. Savings can be achieved by tuning the heating ventilation and air conditioning systems, and no-cost or low-cost measures such as weatherstripping, caulking, thermostat reduction, reducing ventilation and improved lighting.

It is now possible to build new commercial structures which use 60-70 percent less energy than the average existing building. Such savings can be achieved by treating the building and its environment as a total energy system. This includes use of natural ventilation, use of sunlight for heating and lighting, storage of heat or cold in the walls and floors of the building, increased insulation, recovery and use of "waste" heat, shading to reduce summer heat gain, fewer and better windows and more efficient electrical equipment.

INDUSTRIAL CONSERVATION

The industrial sector uses about 23% of Minnesota's annual energy supply. Most of the energy use is distributed among manufacturing, mining, food processing, paper manufacture, printing, and lumber and wood products. Industrial fuel use is dominated by natural gas (nearly 52%) with coal and fuel oil a distant second (18%) and third (15%) respectively. The industrial sector has shown the most significant improvements in energy efficiency.



Each industrial process has its own unique energy "fingerprint," and conservation opportunities for one company are not representative, either in cost or energy savings, for all companies. The opportunities for industrial energy conservation can be classified in three broad categories: (1) **Housekeeping,** which includes heating, ventilation and air conditioning maintenance, reducing lighting, preventive maintenance of equipment and machinery, replacing broken windows, repairing leaking steam pipes. (2) **Recovery of waste heat and materials recycling** which involves capturing and reusing heat normally exhausted to the outside and reusing materials

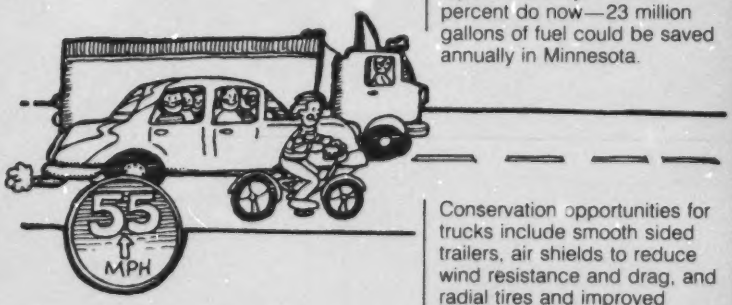
(it takes much less energy to use recycled materials). (3) **Technological innovation** includes the redesign of more efficient plant equipment and manufacturing processes. The latter can be very expensive. Industrial conservation efforts also make extensive use of energy accounting procedures in which the total energy use is split into the energy parts associated with specific industrial processes and the building itself. Once this figure is known, the industry has a baseline against which it can make energy conservation comparisons.

Effective conservation efforts in the commercial and industrial sectors also require constant attention. This means the constant monitoring of energy use, the training and updating of building operators and information and educational programs which encourage employees to take energy conservation seriously.

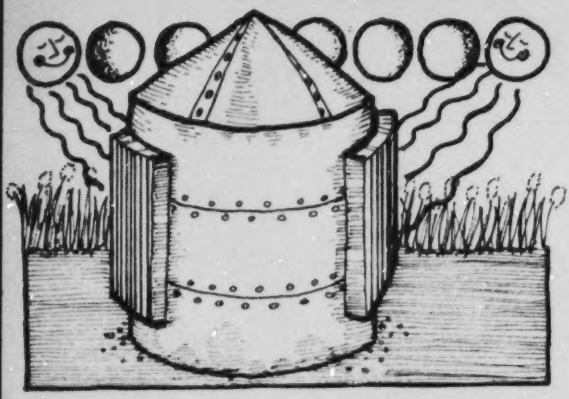
TRANSPORTATION CONSERVATION

Transportation accounted for nearly 27% of Minnesota's energy use in 1978, and consumed over one half of our petroleum. Transportation is Minnesota's thirsty sector; private automobiles are the largest energy users, with trucks consuming the next largest portion. Conservation is very important in this sector because of its total dependence on petroleum products and lack of substitute energy sources.

Because personal travel accounts for 54 percent of all motor fuel use in Minnesota, it represents the largest source of conservation potential, at least, in the near term. There is more flexibility and discretion in the use of personal cars as compared with cars used for business and truck transportation for freight. The conservation opportunities include better gas mileage through more efficient vehicles, improved driving habits and vehicle maintenance, greater use of mass transit and ridesharing programs, and personal changes in travel habits such as better trip planning and reducing the number of miles traveled per person each year. It is estimated that if all drivers were to comply with the 55 mph limit—only about 50 percent do now—23 million gallons of fuel could be saved annually in Minnesota.



Conservation opportunities for trucks include smooth sided trailers, air shields to reduce wind resistance and drag, and radial tires and improved lubricants. Additional fuel savings could also be achieved through greater compliance with the 55 mph speed limit, elimination of one way truck loads and reduced engine idling at transportation terminals.



AGRICULTURAL CONSERVATION

Minnesota's 30 million acres of farm land brought in enough income for the state to be ranked fifth in the nation for total cash farm income. Despite this status, agriculture uses only 6 percent of the state's total energy supply.

However, American farming has increasingly moved toward greater mechanization and, in order to sustain ever increasing yields per acre, the use of petroleum-derived chemical fertilizers. There is considerable disagreement about the advantages and disadvantages of this kind of "energy-intensive" agriculture. Like transportation, agriculture relies heavily on petroleum and remains vulnerable to supply disruptions.

Savings can be realized through a number of low-cost and highly effective conservation measures. Interest in minimum and no-tillage farm production systems is growing. In this kind of agriculture, crops are planted without conventional tillage (no plowing or disking before seeding) or with reduced tillage. After planting, no further cultivation is done before harvesting. Weed control is managed by herbicides. The principle of reducing the number of tillage operations not only saves energy but gains other benefits: reduced labor, and soil and water conservation. Part of the saving is canceled out by the cost for energy to produce chemicals for weed and, sometimes, insect control.

Crop drying often requires as much energy as was used to grow and harvest a crop (excluding the sunlight which nature provides). Corn is the primary crop dried in Minnesota and the energy used can be reduced by using more energy-efficient drying methods. Fast drying methods usually require more energy. Slow drying methods use more of the natural drying ability of air.

LAND USE CONSERVATION

In the past, the way we have developed land for housing, transportation and commercial development, has been without regard for its impact on energy consumption. Land use has been shaped, to a large degree, by transportation, especially the private automobile. One result has been a segregation of different types of land use into its own area rather than a mix of uses in the same area. This has increased transportation needs. Energy must become a more important concern in making these decisions.

Opportunities for conservation through improved land use include those for individual

buildings and for developmental patterns. Orienting buildings to the south and landscaping can save energy. Because solar access can be blocked—by vegetation, by development, by neighboring buildings—buildings must have access to the sun if solar systems are to work. Earth-sheltered construction techniques should also be encouraged.

Environmental sensitivity, energy planning and economic feasibility must be increasingly linked as we develop land for human use. Energy can be saved by building housing close to transit services, near employment, and near shopping centers. Development that builds on pockets of undeveloped land within an urban area, rather than on the open space which surrounds a city, would also save transportation energy and on the energy required to construct new sewers, water and utility services; plus provide social services such as police and fire protection. Higher density development also saves transportation energy and improves the potential for district heating. Buildings with shared walls such as townhouses and apartments use less energy for space heating and cooling than single-family homes. If light industrial, commercial, and residential uses are combined in one area, "waste energy" can become another's useful energy.

Changes in land-use patterns will not be made without difficulty. Our present land-use patterns and regulations were developed in a time of cheap energy and the automobile. There are strong preferences for a "home in the country" and a workplace somewhere else. The existing pattern will take decades to be "retrofitted" with more energy-efficient systems.

Barriers To Energy

When we talk about improving Minnesota's energy efficiency, we must also be aware of forces which make conservation goals difficult to achieve. The energy laws represent one kind of built-in limitation - an upper limit to our efforts. The First Law of Thermodynamics can help us find out where energy is lost, and how to stop some of the losses; the Second Law of Thermodynamics provides a new way to think about efficiency: the goal in using energy for services such as heating or lighting or transportation is to use the minimum amount the energy task requires. In some respects it may be useful to think of these limitations as opportunities because we are still far from reaching the limitations. Buildings represent another limitation. It is not possible to replace all our buildings with energy efficient buildings in a short period of time. There are other barriers which fall in the area of public policy. Some of these include...

ENERGY PRICING

Perhaps the most important barrier to short- and long-term energy conservation in Minnesota has been misleading energy prices. They have made energy conservation a less attractive option and have undervalued its worth.

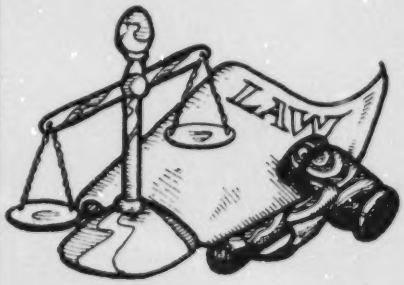
Conservation

Currently, Federal policy holds the cost of natural gas below the cost of replacing this fuel with new supplies. Gas from new wells is much more expensive than that from older wells, due to increasing exploration, production and distribution costs. Energy companies are permitted to average the cost of new, more expensive gas with that of older gas. This average cost is misleading. Consumers are given a signal that the price of a unit of new gas is equal to the "averaged" price, when, in reality, it may be as much as twice as high. Conservation investments appear less economical to consumers than they really are, because projected fuel savings are considered in terms of current, averaged prices rather than reflecting replacement costs.

In addition, there are many indirect costs that are not easily taken into account when we compare the cost of energy conservation to the cost of using traditional fuels. Some examples include federal subsidies for environmental cleanup, the military costs of protecting our interests in oil-producing regions, health effects resulting from energy production and use, and the economic disruption caused by the hemorrhage of dollars to pay for oil imports from other states and nations.

We also tend to underestimate the benefits of conservation in relation to other investments. Comparison of two alternative purchases is always difficult. Most of us find it easy to think about the purchase price of an item. The next step in an energy cost analysis is to consider the **payback period**. This is the time it takes to get back what was paid in. If it costs $60 (do-it-yourself) to caulk and weatherstrip windows and doors and the annual energy savings is $110, the payback period is 6 months, or if the addition of storm windows cost $290 and the annual energy savings are $65, the payback period is 4.5 years (290 ÷ 65 = 4.5).

An even more sophisticated approach to the question of energy cost involves **life cycle costing** which combines the initial cost, payments for interest, taxes, insurance costs, future fuel costs and routine operating and maintenance costs of an item—this could be a home or a power plant—for each year of its lifetime. A constant monthly or yearly payment can then be computed and comparisons made. Could the need for a proposed new power plant be met through conservation measures? Which combination of energy conservation improvements have the lowest possible monthly costs? When this kind of analysis is done it puts conservation on an equal footing with competing energy investments in traditional fuels. The term "total cost" is often used as a synonym for life-cycle cost.



DECENTRALIZED DECISION MAKING

Almost everyone is (or can be) involved in decisions to conserve energy. Our personal values, in combination with existing laws and regulations

about energy conservation, make the job of educating such a diverse group of conservation decision makers a large one. The number of people and organizations involved in conservation decisions makes it difficult to change the system quickly.

Take the case of rental property. Tenants pay the fuel bills and are reluctant to invest money for extensive conservation improvements in someone else's property. Because the owner doesn't pay the fuel bill s/he is unconcerned. In this country you don't impose uniformity. Or do you? In Minnesota we did. The rental retrofit law set mandatory standards for rental units. Weatherstripping and caulking by January 1980. Other measures such as insulation, storm doors and storm windows by January 1983.

The Minnesota Home Energy Disclosure Law became effective in 1980. It requires a seller of a home built before January 1976 to provide an energy audit to a buyer when a purchase agreement is signed. The law is designed to help encourage energy conservation in Minnesota's homes. Each home is evaluated on more than 20 standards, e.g., weatherstripping, caulking, storm windows, storm doors, and insulation. The law applies to houses, rental units, condominiums, and mobile homes. However, the buyer may waive the audit and most are doing just that.

Some barriers can be readily identified and changed; others will be very difficult.

INFORMATION AND EDUCATION

Consumers can contribute to Minnesota's energy and economic interests by investing in products that reduce energy use.

In efforts to reduce energy costs—and in response to government encouragement, including tax credits—consumers spend billions of dollars each year on energy saving products. However, consumers face problems with advertisements designed to induce them to purchase such products.

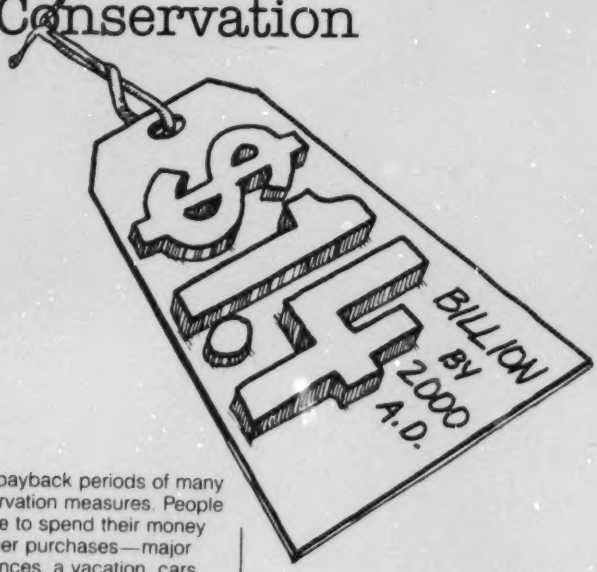
How can consumers determine the accuracy of energy saving claims when data that sellers provide consumers to support claims are sometimes inaccurate, not relevant or highly technical? When some advertisers will not furnish consumers with adequate material to substantiate advertised claims? When performance is difficult to measure?

Efforts to conserve energy will confront such obstacles. Consumers must have access to accurate, objective information to help them identify conservation actions which are in their economic interest. A dollar invested in wise energy conservation saves money. But who and what to believe are important questions. Education, alone, does not act as a strong enough incentive to save energy. There is also...

COST

Consumers regularly identify the cost of conserving as a major barrier. Many find it easier to pay monthly fuel bills than to finance energy conservation projects. The problem of the cost of conserving persists despite the

Energy Conservation



short payback periods of many conservation measures. People choose to spend their money for other purchases—major appliances, a vacation, cars. For many, the household/business budget faces very strong competition from other expenditures.

To reach the "target goal" of a reduction in Minnesota energy demand by 2000, the commercial sector alone will need to invest $1.4 billion in energy conservation. This is a large sum of money and will increase with inflation. A good reason for making such an investment is that by 2000 the Minnesota energy bill will be in the neighborhood of $30 billion. Our 1980 bill was $6 billion. Save energy: save money.

How to encourage conservation is a continuing source of controversy. Do we educate, regulate or work to change conservation's public image? Are there other ways to help?

At present, Minnesota government programs provide grants and low interest loans for weatherization to those who can meet stringent income requirements. There have been bills introduced in the legislature which would make it profitable for utilities to invest in home conservation improvements and alternative energy systems. Such programs would encourage home energy retrofits by providing money to those who fall just short of stringent income requirements and those who find it difficult to finance large investments in conservation.

Minnesota's Energy Picture:

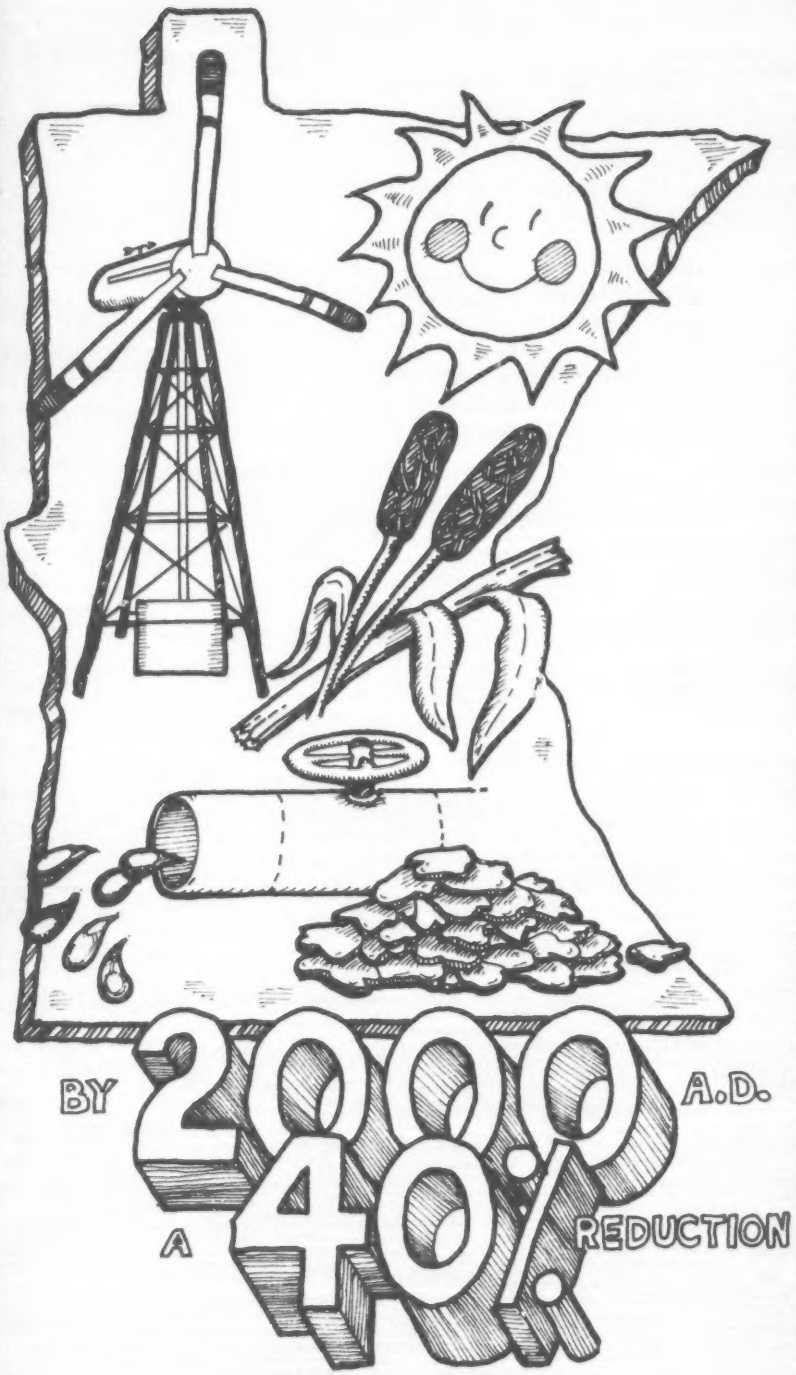
Alternative Energy Sources

Minnesota has relatively abundant alternative energy resources that have positive economic effects, low environmental impact, and are renewable. Four major renewable resources have the greatest potential: solar, wind, crop residues, and special energy crops. Many solar and wind technologies are already economically attractive.

In the longer term, a rich biomass potential and district heating can provide significant portions of Minnesota's energy needs. Major biomass resources include special energy crops, such as cattails, and residues from conventional agricultural crops. Biomass energy sources with lower potential include conventional agricultural crops, wood, urban solid wastes, and farm animal wastes. Peat, a nonrenewable resource, may provide significant quantities of energy in the transition to special energy crops.

According to a Minnesota Energy Agency projection, alternative energy resources can supply 40% of Minnesota's energy demand by 2000. Of these, direct solar energy would provide 8.5%; wind 2.1%; hydro .4%; crop residues 6.5%; animal wastes .3%; special energy crops (plus peat) 17.9%; urban wastes .4%; and district heating 4.2%. These alternatives could meet 70% of our heating fuel oil use, 30% of our gasoline use and 39% of our conventional electricity use by 2000.

There are also economic benefits to Minnesota. Dollars spent on these energy resources will stay in Minnesota to produce jobs and other economic benefits. And Minnesota's energy supply system would be substantially based on renewable rather than nonrenewable resources, thus providing a stable source of energy for the future.



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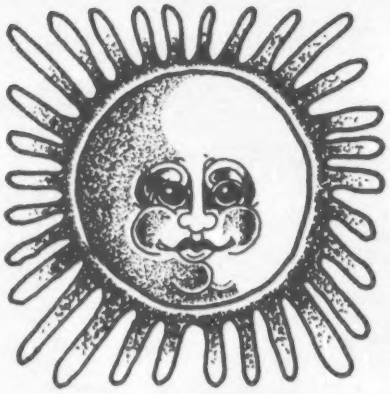
Solar Power
Active Thermal and Passive Thermal



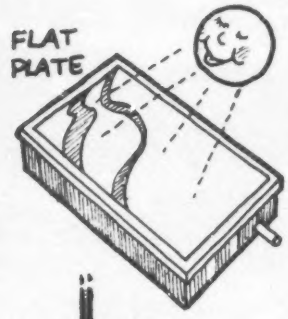
Solar thermal systems convert sunlight into heat. There are two kinds: Active Thermal and Passive Thermal systems. In passive systems the building collects and stores solar energy without the use of mechanical equipment. In active systems, solar collectors convert the sun's energy to useful heat by mechanically forcing air or a liquid through the collectors to transport the sun's heat.

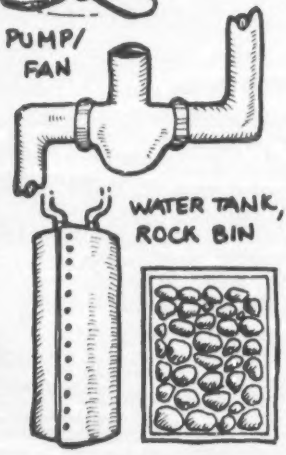
Thermal systems consist of four basic components: a collector, a heat transfer device, storage and control units.

Sunlight can be blocked by vegetation and by other buildings. Solar access is of vital concern to the development of solar energy and will require changes in planning, zoning and subdivision regulations as well as their strict enforcement. Minneapolis was the first city in Minnesota (and the first large northern city in the nation) to adopt a comprehensive solar access protection ordinance.

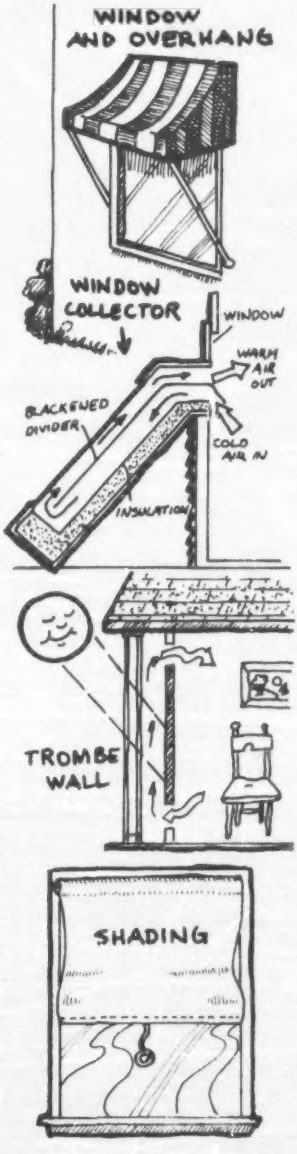
In general, solar thermal energy is relatively benign but there are environmental concerns. These include: aesthetics (some people don't like solar collectors in their neighborhoods); light reflection from the glass of a flat-plate collector may bother neighbors; some passive designs can cause overheating, releasing hazardous indoor air pollutants from greases and resins used in construction materials; many active systems use anti-freeze to prevent freezing in the winter months (this must be replaced after four or five years and disposal of these fluids into waterways and landfills may cause some environmental hazards); and resource use. (Will a large hardware demand significantly deplete resources such as copper? Will emissions by industries that produce raw materials for collectors increase water and air pollution, e.g., increase the amount of acid precipitation?)

ACTIVE THERMAL

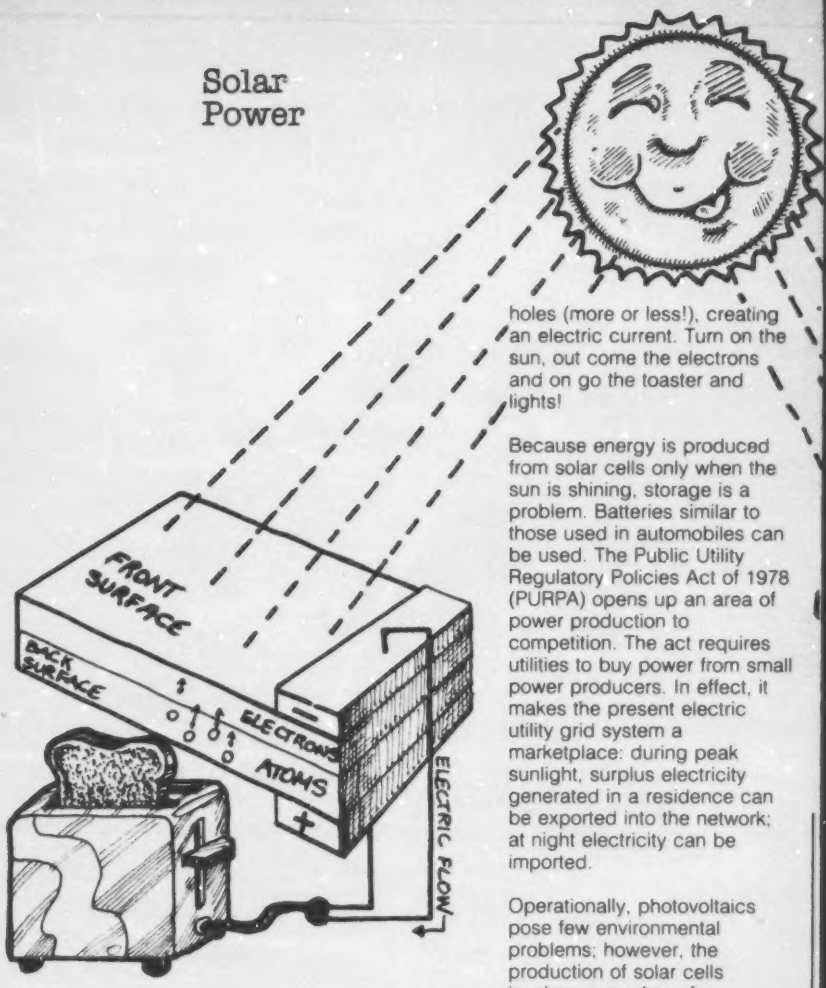




PASSIVE THERMAL



Solar Power



Photovoltaic Electricity

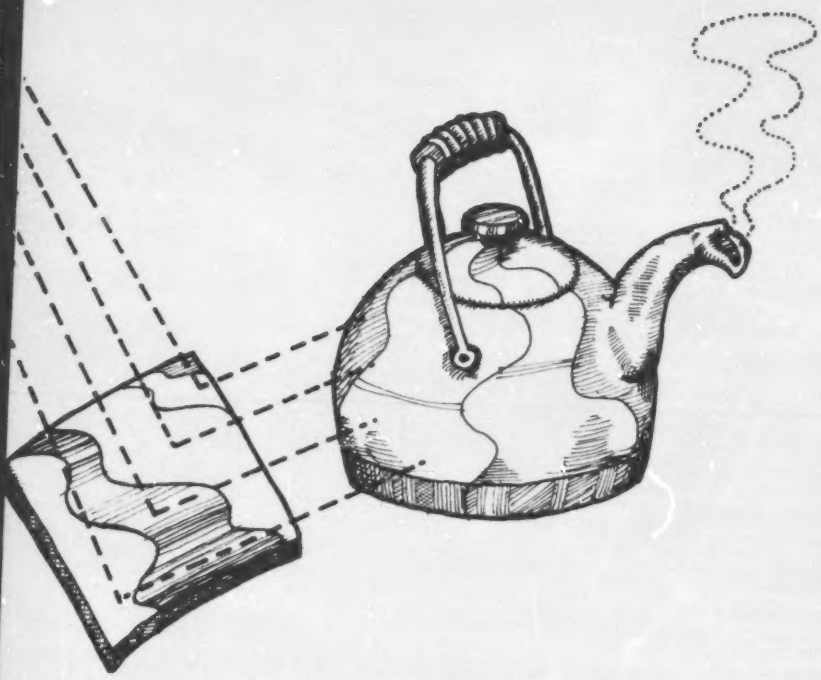
Solar photovoltaic (PV) or solar cells convert sunlight directly into electricity. Solar cells are a sandwich of two dissimilar materials—the most common are made of pure silicon (the major constituent of sand) and contaminated with precise amounts of other materials.

Think of sunlight as a stream of bullets called photons. As each hits the surface of a cell, the light energy knocks an electron (a negative particle present in the outer "shell" of an atom) loose and leaves a positive hole behind. When a solar cell is connected to an electric circuit, the light-generated electrons fall into and move through the light-generated holes (more or less!), creating an electric current. Turn on the sun, out come the electrons and on go the toaster and lights!

Because energy is produced from solar cells only when the sun is shining, storage is a problem. Batteries similar to those used in automobiles can be used. The Public Utility Regulatory Policies Act of 1978 (PURPA) opens up an area of power production to competition. The act requires utilities to buy power from small power producers. In effect, it makes the present electric utility grid system a marketplace: during peak sunlight, surplus electricity generated in a residence can be exported into the network; at night electricity can be imported.

Operationally, photovoltaics pose few environmental problems; however, the production of solar cells involves a number of environmental and human health hazards. Some of the chemicals used in manufacturing are toxic, e.g., cadmium, arsenic and hydrogen cyanide. Silicon dust is a respiratory irritant and can cause chronic respiratory problems (silicosis).

Photovoltaic conversion of sunlight to electricity is expensive—25 to 50 times more expensive than power plant electricity—and is likely to remain so until at least 1985. As energy costs increase, solar cell efficiencies improve and materials and manufacturing costs decrease, solar cells will become much more competitive in the more distant future. Because of the great value we place on electrical energy and the fact that solar cells appear to have relatively minimal and manageable effects on the environment, their practical potential is large.



Thermal Electric

Thermal Electric systems use lenses or mirrors to concentrate light on a boiler. The steam (kinetic energy) produced by the boiler is used to turn an energy conversion device called a turbine which runs an electrical generator. This process converts the kinetic energy of a moving gas to mechanical energy to electrical energy.

The tendency in research on such systems has been to emphasize large-scale methods. The "power tower" near Barstow, California is one such device: 72 acres of small computer controlled mirrors concentrating their sunlight on an 80-story tower. However, smaller, less-centralized systems also show great promise, especially for industrial applications. Such thermal electric systems can be used to generate electricity; and the "waste" heat (Remember Thermodynamics II!) can be used for space heating, industrial processes and stored, which assures the steady operation of the turbine-generator.

Large-scale solar thermal electric systems clearly have significant environmental impacts: acres and acres of land. Small-scale systems may require only rooftops or other low-use land areas around industries.

At present, the mirrors and lenses, designed to track the sun, are very expensive. Solar thermal-electric systems appear more feasible in the high-sunlight areas of the southwestern United States. Costs are expected to drop in the next 5 years and this energy conversion technology may then become more feasible in Minnesota, especially in applications where the "waste" heat is used.

Solar Power

Chemical Fuel

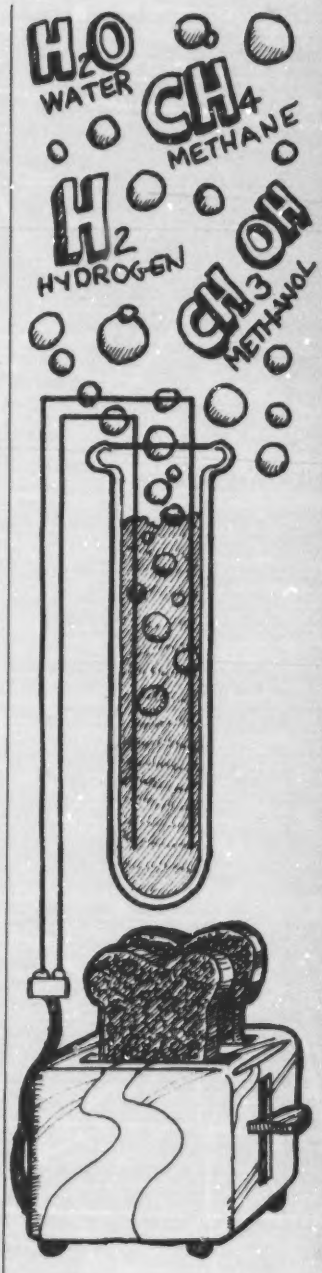
In Chemical Fuel conversion, the sun is used to produce solid, liquid, or gaseous fuels. There are many different types of such systems, e.g., electricity produced from photovoltaics can be used to split water into hydrogen gas. In another process, methane (gas) or methanol (liquid) is made from limestone and water.

One of the significant advantages of these kinds of fuels is that the required transportation, storage and the energy conversion systems already exist. Furnaces would not have to be replaced, automobiles would still use liquid fuels and many industrial processes could continue unchanged.

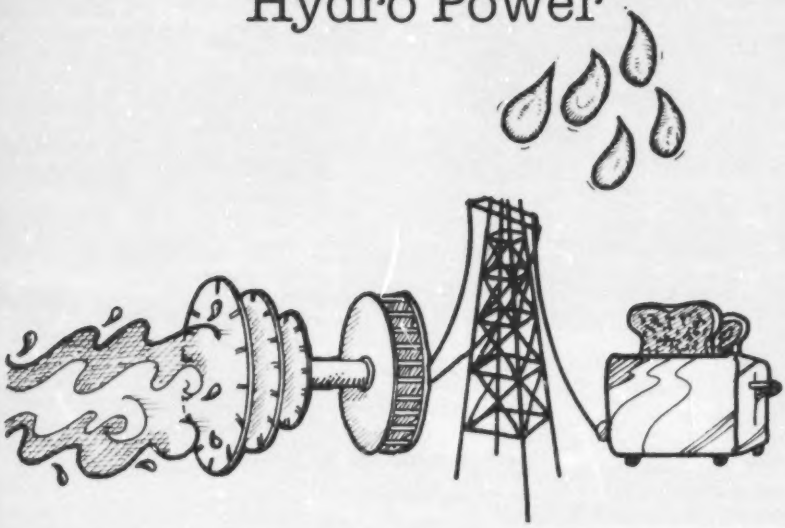
Environmentally, many of these solar fuels are essentially nonpolluting, however, technology used in their production would release a variety of noxious materials, primarily air and water pollutants. In general, most such emissions would be small.

At present, the technology for many solar chemical fuels is not yet available nor economical although in some cases the innovations required are considered by some observers to be bogged down by a lack of development money. Because these fuels are so diverse, and so readily match present technology, they have great potential.

The economical production of solar fuels depends on technological breakthroughs. Their promise is so great that these fuels could renewably meet all of Minnesota's current energy needs with energy forms (liquid and gas) already compatible with existing fuel-using equipment.



Hydro Power



Flowing water in streams and rivers has been used to produce electric energy in Minnesota for almost 100 years. The first hydroelectric plant in the Western Hemisphere began operation September 6, 1882, on Upton Island in the Mississippi River. It produced electricity for 60 lamps along Minneapolis' Washington Avenue.

Thirty-one dams currently produce power. The average height of these hydropower dams is about 40 feet and they range in height from 12 (Cold Spring) to 95 (Fond du Lac) feet.

The energy available from dams in Minnesota varies by season. Spring, and sometimes fall, are usually the periods of greatest stream flow in Minnesota, and are the times when the peak energy potential from hydropower is available.

There are two ways to capture the water's energy. In a conventional hydropower system, a river's power is captured by dams erected on it. The dams direct the fast-flowing water through turbines, turning generators and producing electricity. In this system, the amount of power generated is dependent on the head, or essentially the height of the water, and the rate of flow of water through the turbine.

The other method is to remove the energy from the stream as it flows naturally. In-stream turbines consist of a series of large, wing-like blades. Flowing water causes the blades to turn a shaft which turns an electric generator. Such turbines must occupy most of the stream width and depth to extract maximum hydropower and because such large installations would be required, it is not likely these systems will be built in Minnesota.

Dams influence the environment in several ways. Silt settles upstream as water movement is slowed. This changes the river bottom and causes changes in river plants and animals. Flooding also creates new shorelines which may prevent other uses such as agriculture and forestry. Dams interfere with fish migration and block recreational use of streams. In both dam and in-stream systems, fish may be damaged by the turbine although this problem appears to be minor.

Because of environmental (most undeveloped sites are located on the scenic North Shore) and economic factors, it is probable that no new dams will be built within the next five years. The largest potential for expanding hydropower energy lies with reactivation of former dams and expansion of existing hydropower dams.

Wind

Wind is a form of solar energy. Wind is caused by the uneven heating and cooling of the Earth's surface. As the land warms, the air above it is also warmed. Warm air rises and cooler air rushes in below to take its place—creating a gentle breeze or a roaring gale.

Wind energy can make an impressive contribution to Minnesota energy requirements. At an altitude of 150 feet, wind speeds in Minnesota may average almost 15 mph, regardless of the geographic location. Trees and hills reduce average wind speeds at altitudes under 150 feet. There are two important things to remember about wind: (1) the energy content of wind increases immensely with wind speed (A 20 mph wind has eight times as much power as does a 10 mph wind); and (2) it is possible to harness about 60% of the energy in the wind.

Energy from the wind is converted by a turbine which resembles aircraft propellors although there are many variations. One of these, the Darrieus, looks a little bit like an egg beater.

There are two wind energy conversion systems: (1) Wind Electric in which the turbine turns an electric generator; and (2) Wind Thermal in which wind energy is converted to heat by agitating a fluid, or turns an electric generator using the electricity in heating elements (like a toaster).

In small wind electric systems, excess electrical energy can be stored in batteries for use at times of low wind speed although a wind electric system can also be interconnected to a utility, and excess power may be fed into utility lines. When the wind system does not produce enough electricity, the additional energy is supplied by the utility.

Would large-scale use of wind reduce air flow enough to influence weather patterns? No one knows for sure. Some potential problems are: (1) aesthetic—large structures have high visibility; (2) distortion of some television and radio signals—a significant problem near large wind systems, although new blade materials may reduce this problem; (3) impact on migratory birds—though there is no firm evidence of significant impact, this could be a problem in some areas; (4) impacts associated with construction of transmission lines to connect wind systems to an electric grid; (5) liability and safety from blade breakage or icethrow (ice build-up on turbine blades that slides or is thrown off during turbine rotation); and (6) noise.

Biomass

There are difficulties in collecting, storing and distributing solar energy. Sunlight, while abundant and inexhaustible, is also diffuse. It varies in intensity seasonally and is intermittent. One solution to these problems is to take advantage of an established natural technology which stores energy. In the presence of sunlight, plants manufacture carbohydrates from carbon dioxide and water.

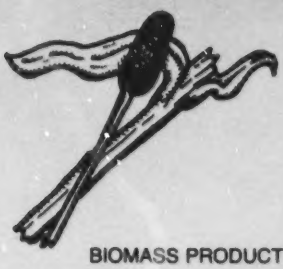
We refer to the stored chemical energy of plants as biomass. Major renewable biomass resources include special energy crops such as cattails, regular farm crops, agricultural crop residues such as cornstalks, cobs and wheat straw, wood, urban solid wastes and farm animal wastes. Biomass also includes peat, an essentially non-renewable resource. This dead, partially decayed plant material is a product of plant accumulation in wet environments during the last 2,000 to 10,000 years. It is sometimes called a fossil fuel and may be thought of as geologically young coal.

Biomass production is a particularly attractive alternative energy resource because the energy source is close to where it is needed, sunlight and water are available, and it is comparatively easy to convert these materials into high quality liquid and gaseous fuels. It is also an attractive solid fuel.

Some of the major implications of using each biomass energy alternative are briefly summarized in the table in relation to the type of land on which it is produced. An important constraint on using biomass for energy is that such materials are currently or potentially more valuable as food or raw material.

Furthermore, large land areas would be required in order to achieve significant production of most biomass forms. Biomass production requires more careful environmental assessment and control in comparison with other renewable alternatives because of the large requirements for land as well as for plant fertilizer and water.

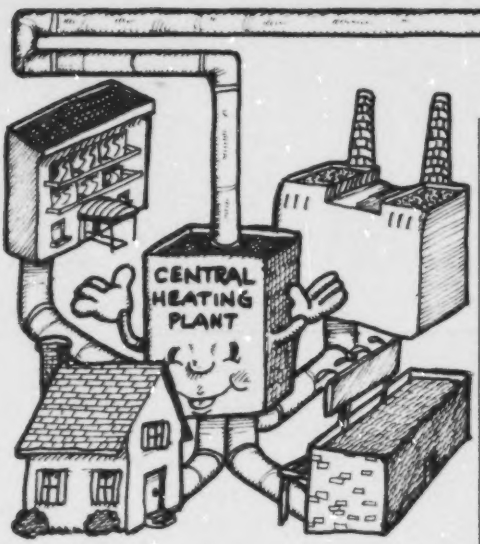
The term for the transformation of biomass into usable energy is **bioconversion.** There are three basic methods. One is direct burning of biomass into heat energy or for use in generating electricity. The Grand Marais school system has heated its schools entirely with sawdust and wood chips since 1978. The second is the use of physical or chemical processes to convert biomass into gases and liquids. At high pressure and temperature peat can be converted to synthetic natural gas (methane). In the third method, bacteria are used to break down biomass into gases and liquids. Yeasts have been used for centuries to change sugars into alcohol which can be used directly in suitably modified cars and tractors or mixed with gasoline (gasohol). Alcohol can be produced from a variety of plant and animal matter, corn, sugar beets, cattails, wood chips, Jerusalem artichokes, as well as from agricultural by-products and wastes. The material left over from the process, called distiller's grain, is a valuable, high protein animal feed.



BIOMASS PRODUCTION	RESOURCE
FARMLAND	
• Conventional Agricultural Crops (20.5 million acres, 1978)	Corn, soybeans, wheat, oats, barley and hay
• Agricultural Crop Residues	Above ground portions of plants that remain after harvesting
• Animal Manure and Bedding	Livestock manure and urine Bedding materials
FOREST LAND (15 million acres)	
• Wood and Wood Residues	Wood refers to tree trunks. Wood residues are tree branches, twigs, leaves and by-products of wood processing such as bark, sawdust and wood edgings.
SPECIAL ENERGY LANDS (11 million acres)	
• Special Energy Crops (3.8 million acres)	Crops grown for their energy content, e.g., cattail, alder and willow
• Peat (7.2 million acres, 160 years energy supply)	Formed from the accumulation of dead bog plants in a wet environment such as undrained glacial lake basins and depressions The average thickness is 7 feet.
URBAN AREAS	
• Municipal Solid Waste	Trash Industrial refuse
• Municipal Sewage	Human digestive wastes Food wastes Commercial and Industrial liquid wastes

COMPETING USES	ENVIRONMENTAL IMPACTS	AVAILABILITY AS AN ENERGY RESOURCE
Food and animal feedstock	Soil erosion Fertilizer runoff Pesticide and herbicide effects	It would require planting 2 million acres of farmland not now used for crops and depend on food shortages or surpluses, i.e., in a bad year the crops would be used for food. Crops are not expected to be an important energy resource.
Plowed under and used as a soil conditioner and source of nutrients	Crop residues slow topsoil loss and, when plowed under, maintain soil porosity	It is believed that about one-third of the present total of crop residue can be safely removed. These can be a significant energy source.
Fertilizers Poultry manure can be used for animal feed	Not considered significant. After energy conversion, the remaining material can still be used for fertilizer	The collection and drying of these materials limits widespread use. This resource is most economical for large feedlot and poultry operations where the energy produced can be used to run these operations. A small source of energy in Minnesota.
Paper Lumber Lumber substitutes (waferboard for plywood)	Removal of logging residues also removes nutrients that would be added to the soil by decay. Fertilization might have to be increased. Recreational value could decline with intensive forest mangement.	Within 10-15 years, the forests of Minnesota may be almost completely used for nonenergy needs. Use of wood for energy is expected to remain small.
Open-space Wilderness Wildlife habitat	There are impacts associated with planting and harvesting but these are minimal and manageable.	The greatest potential of any renewable biomass energy resource. There are large areas of land available for the growth of these energy rich plants. The Energy Agency favors growing energy crops such as cattails on large "energy plantations" scattered across the peatlands.
Timber Horticulture (Sphagnum moss) for potting plants Agriculture: growing cranberries, truck gardens, soil conditioner. Peatlands are prospective areas for special energy crops.	Peat plays an important and poorly understood role in water regulation. Recreational, educational and scientific uses. Air pollution (dust).	Peat can be an important energy source but there are too many environmental unknowns for massive peat land mining. State officials urge slow and small program development of the energy resources peatlands have to offer.
Recycling for use in production of paper products	Plastic and metal components may produce hazardous air pollutants.	The energy benefit is in recycling the resource. Not a significant energy source in Minnesota.
None. Energy conversion preserves value of the material as soil conditioner and as plant nutrients.	Beneficial	Its use in waste treatment plants would reduce the growing energy requirements of such facilities. Not a significant energy source in Minnesota.

District Heating And Cogeneration



In district heating, steam or hot water from a central heating plant is piped to commercial, industrial and residential (primarily apartments) buildings to provide heat, hot water and steam for processing needs. The water/steam is then returned to the plant to be reheated before it returns through the sytem. The heat source can be a boiler designed just for district heating, or it can be a cogeneration district heating system.

Cogeneration systems use the waste heat from electricity-generating plants for district heating. The fuel in such systems does two jobs instead of one. The electrical utility gains a new source of income and the fuel is used more efficiently.

At one time there were more than 30 district heating systems operating in Minnesota communities; today there are only 14. In the early 1950s, these systems began to be replaced because of the availability of cheap oil and natural gas. Today as fuel prices have increased, many communities are enthusiastic about restoring or constructing district heating systems, but the initial costs often run into the millions of dollars.

St. Paul has plans to replace an old system with a large hot water system hooked into a power plant that will eventually heat the Capitol complex and industries and apartment buildings in the downtown area. Minneapolis has a 10-year old, privately owned district heating system which heats a number of downtown buildings. There are proposals to hook this system into a power plant and to convert the system from oil and natural gas to coal.

Red Wing and Moorhead have plans to develop new hot water district generating systems and two cities on the Iron Range—Hibbing and Virginia—already serve large residential heating districts and hope to upgrade and expand their systems.

As fuel prices increase and the threat of fuel shortages mount, district heating is one option that some Minnesota communities will probably explore. Such systems, while expensive, are safe, discourage continued urban spread, conserve energy, help communities become more energy self-sufficient, reduce air pollution, and can even use renewable energy fuels.

Minnesota's Energy Picture:
Two Equity Issues

All of us share some of the same concerns about energy. One of these is cost. A consequence of the rapid rise in the cost of energy is an accentuation of differences between energy "haves" and "have nots."

PEOPLE

The energy crisis hits the poor the hardest, and low income energy users face a special set of energy problems.

The poor use less energy than others. They use less fuel to heat their homes, less electricity for lighting and appliances and less gasoline. The substantial and increasing proportion of a low income family's budget which goes for energy affects their ability to pay for other essentials such as food, housing, and clothing, which account for almost all of the remaining income after energy costs are paid.

The number of low income households in Minnesota is between ten and twenty percent of the state's total population. Those low-income households using natural gas spend approximately 25 percent of their income for fuel and electricity, compared with 45 percent for households burning fuel oil.

What are some of the basic energy-related needs of low income people? In the short-term, emergency assistance when they cannot pay their energy bills. In the long term, weatherization assistance for ceiling and wall insulation, storm windows and doors, caulking and weatherstripping, window repair, and plugging of air leaks; furnace maintenance and repair; self-help training; information on low-cost, no-cost measures; and incentives such as low or no-interest loans for

landlords and homeowners to weatherize buildings. Over the long run, the most effective way to help the poor is through conservation.

STATES

Only a few states produce all the energy they need. States exporting raw energy resources—coal, oil and natural gas—charge a severance tax. It is a tax imposed on mining or extraction of natural resources.

In 1979, severance taxes on the production of coal in Montana and Wyoming cost Minnesota consumers about $24 million. The states justify the taxes as a way of repairing environmental damage from mining; providing community services such as roads, schools, water and sewer systems for energy "boom towns;" and developing an economic base for the day when the energy resources are depleted.

States importing coal regard some of these levies as "exorbitant," and Montana was sued over its 30 percent severance tax by 11 out-of-state utilities. The U.S. Supreme Court ruled in July, 1981, that Montana has the right to tax its natural resources.

Much of the West's coal comes from federal lands, and bills have been introduced in Congress which would impose a 12.5 percent ceiling on state severance taxes on coal. These bills face very stiff opposition, and the conflict over the distribution of resources and wealth between energy "have" and energy "have not" states is likely to become an intense and potentially bitter issue.

What Can A Teacher Do?

You may never know enough about energy or have all necessary energy information at your fingertips or have the "right" collection of classroom energy teaching materials or the money or the preparation you would like in order to teach energy.

But what you do know about is teaching and learning. From all the tasks people assign to teachers, suppose we emphasize just one: to maximize opportunities for learning. This includes knowledge, skills and the discovery and development of personal meaning. Teachers know how to learn and, therefore, how to help kids learn about energy. These are very special skills. You do not have to have particular knowledge of energy but a willingness to leap into the dark (there is no substitute) and to help kids find meaningful intervention points. The study of energy is an opportunity to build skills in problem identification, investigation techniques, analysis of changing problems, and in learning how to choose among alternatives.

Dr. Mary Budd Rowe wonders what might happen if all students learned to ask the following questions routinely. Such questions should help you and your students in learning about energy.

ON EVIDENCE

- What do I know?
- Why do I believe it?
- What is the evidence? Do I have it all?
- Where did the evidence come from? How good is it?

ON INFERENCE

- What do I make of it?
- What are all the possible interpretations?

ON ACTION

- What must I do with what I know?
- What possible actions should I take?
- Do I know how to take an action?

ON EVALUATION

- What does it all mean?
- Do I value some outcomes more than others? Why?

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Learning Materials

Energy education materials have been developed by the Minnesota Department of Education and the Minnesota Department of Energy, Planning and Development. These include learning materials for grades K-6; junior high science and social studies; secondary home economics, industrial arts education, science and social studies; vocational education (service occupations); communications (grades 4-8); driver safety and energy conservation (for 9th and 10th grade general mathematics and driver education); modern languages (for 3rd year students in French, Spanish); and environmental and outdoor education activities.

For more information about curriculum materials and energy education programs write:

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*Unless otherwise noted, the content of this energy primer is based on the **1980 Energy Policy and Conservation Biennial Report DRAFT** of the Minnesota Energy Agency. An Executive Summary of this report is available in your school Resource Center.*